priorities

1999~2001 Priorities and Progress under the Great Lakes Water Quality Agreement

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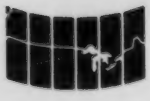

Report to the
International
Joint Commission

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Introduction

INTRODUCTION

In the **Great Lakes Water Quality Agreement**, the **United States and Canada** (the Parties) agree "to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem." To achieve this purpose, the Parties have undertaken numerous programs, policies and other measures and have obligated themselves to periodic reporting on their progress.

The International Joint Commission's (IJC) role is to evaluate and assess the Parties' programs and provide a report at least every two years that presents its findings, advice and recommendations. To fulfill its evaluative role, the IJC relies upon numerous sources. A major source of information and assistance are the two joint institutions established under the Agreement – the **Great Lakes Water Quality Board** (WQB) and the **Great Lakes Science Advisory Board** (SAB).

As principal advisor to the IJC, the WQB comprises 20 program managers and administrators from the two federal governments, the eight states and two provinces in the Great Lakes - St. Lawrence River basin. The SAB, whose 18 members represent a broad range of disciplines, provides scientific advice to both the IJC and WQB.

In 1984, the IJC established the Council of Great Lakes Research Managers (CGLRM) whose 22 members provide advice related to the coordination and evaluation of Great Lakes research efforts. Given the significance of the air as a pathway by which contaminants reach the waters of the Great Lakes, the IJC relies on its International Air Quality Advisory Board (IAQAB), established in 1966 under the auspices of the Boundary Waters Treaty, to provide advice in this regard. The IJC also establishes task forces and other groups to address specific issues or subjects that are particularly germane to fulfilling the Agreement purpose.

Recognizing the need to secure the views and opinions of basin stakeholders, the IJC engages in a variety of public consultation activities. The information received from this broad-based consultation contributes significantly to the insight, advice and recommendations that the IJC provides to governments through its biennial reports.

To manage its human and financial resources, the IJC establishes priorities based on the advice it receives from its advisory boards. The priorities for the current 1999-2001 cycle were adopted by the IJC Commissioners in the fall of 1999 after the 1999 Great Lakes Water Quality Forum held in Milwaukee, Wisconsin. The 1999-2001 priorities are summarized in the following table. Responsibility to undertake the priorities was assigned to the WQB, SAB, CGLRM and IAQAB.

The four chapters in this report were prepared by the groups responsible for the identified priorities. They define and describe the specific investigations undertaken to support each priority and present the groups' findings, conclusions and recommendations. No attempt was made to harmonize the content or recommendations, as they represent each groups particular advice to the IJC with respect to their charge and obligations.

COMMISSION PRIORITIES FOR 1999-2001

Priority	**Review of Programs Regulating Introduction of Biological Pollution (Alien Invasive Species) into the Great Lakes**	
Summary	To assess the various regulatory programs in place attempting to control introduction of biological pollution and provide recommendations as to additional and changes to existing Great Lakes regulatory programs.	
Responsibility	Lead:	Great Lakes Water Quality Board
Product (Chapter)	1.2	Alien Invasive Species and Biological Pollution of the Great Lakes Basin Ecosystem
	3.6	Invasive Species Research

Priority	**Assessment of Progress Under Great Lakes Binational Toxics Strategy**	
Summary	To assess progress toward achievement of the Agreement's virtual elimination goal, and to help the Commission develop advice to governments.	
Responsibility	Lead:	Great Lakes Water Quality Board
Product (Chapter)	1.3	Great Lakes Binational Toxics Strategy

Priority	**Investigation of Source-Receptor Relationship for Atmospheric Deposition of Dioxin to the Great Lakes**	
Summary	To model and estimate source-receptor relationships for the atmospheric deposition of Dioxin to the Great Lakes.	
Responsibility	Lead:	International Air Quality Advisory Board
Product (Chapter)	2.3.6	The Use of Atmospheric Modelling in Policy Development and Using Models to Develop Air Toxics Reduction Strategies
	4.2	Ann Arbor Workshop, July 2000: The Use of Atmospheric Modelling in Policy Development
	4.3	Milwaukee Workshop, November 2000: Using Models to Develop Air Toxic Reductions Strategies: Lake Michigan as a Test Case
	4.4	Ambient Measurements - Interpretation and Use
	4.5	Applications of Models
	4.6	Conclusions and Recommendations

Priority	Methodology for Assessing Community Health in Relation to Effects of Aquatic Pollutants	
Summary	To develop a methodology for assessing whether human health effects are occurring in actual subpopulations of humans in the Great Lakes basin.	
Responsibility	Lead:	Great Lakes Science Advisory Board with assistance from its Workgroup on Ecosystem Health and the IJC's Health Professionals Task Force.
Product (Chapter)	2.2.1	Methodologies for Community Health Assessment: Measuring Injury to Health
	2.2.2	Protecting Human Health From Exposure to Contaminants in Great Lakes Fish

Priority	Annex 2: Remedial Action Plans and Lakewide Management Plans	
Summary	To assist the Parties in the development and implementation of RAPs and LaMPs through: conducting status assessments to evaluate activities, workshops to transfer information and foster implementation, and RAP and LaMP reviews in order to gauge progress toward restoration of beneficial uses.	
Responsibility	Lead:	Annex 2 advisory staff in collaboration with the Great Lakes Science Advisory Board and Great Lakes of Water Quality Board
Product (Chapter)	1.5	Remedial Action Plans
	1.6	IJC Request for Advice
	1.7	Criteria for Removal of the AOC Designation
	2.3.5	Remedial Action Plan Assessment: Site Visits to the Niagara River and St. Lawrence Areas of Concern

Other Priorities and Initiatives

Summary	To identify and provide insight and advice on other topics relevant to fulfilling the purpose of the Great Lakes Water Quality Agreement and in accordance with the directive to the Great Lakes Water Quality Board, Great Lakes Science Advisory Board and the Council of Great Lakes Research Managers, including emerging issues.	
Product	1.4	Legal Workshop on Protection of Great Lakes Water Quality from Atmospheric Deposition of Contaminants
	2.3.1	Review of Annex 1 of the Great Lakes Water Quality Agreement
	2.3.3	Nonpoint Sources of Pollution from Land-use Activities
	2.3.4	Evaluation of SOLEC Indicators Relative to the GLWQA
	2.4	Emerging Issues in Great Lakes Science, Research and Policy
	3.2	Ecological Impacts of Changing Demographics within the Great Lakes Basin
	3.3	Emerging Contaminants and Pharmaceuticals in Great Lakes Waters
	3.4	Understanding the Interaction of Ground Water and Surface Water in the Great Lakes Basin
	3.5	Understanding the Long-term Impacts of Water Level Fluctuations, Diversions and Consumptive Uses in the Great Lakes - St. Lawrence River System
	3.7	Frameworks for Modelling Ecological Change in the Detroit River - Lake Erie Corridor

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Recommendations

RECOMMENDATIONS

The following 48 recommendations were developed by the Great Lakes Water Quality Board, Great Lakes Water Quality Board, the Council of Great Lakes Research Managers and the International Air Quality Advisory Board for the International Joint Commission's consideration. Substantiating details are provided in the sections indicated.

GREAT LAKES WATER QUALITY BOARD

The WQB recommends the following to the IJC:

1.2 Alien Invasive Species and Biological Pollution of the Great Lakes Basin Ecosystem 16

- As the core of a preventative, binational approach for addressing the serious threat of alien invasive species in the Great Lakes basin, the Commission should recommend to the Parties that effective binational ballast water discharge standards be developed, implemented and enforced throughout the Great Lakes basin as rapidly as possible. Further, the Commission should recommend the Parties prohibit the discharge of ballast water of any type into the Great Lakes basin from ballasted vessels and from vessels reporting no ballast on board (NOBOB), whatever their origin, that do not meet the binational standards while they are within the Great Lakes basin.

- To aid in achieving the binational ballast water discharge standards, the Commission should recommend that the Parties, in cooperation with shippers and other relevant stakeholders, facilitate an immediate and significant investment in resources directed to the development of effective, long-term ballast water treatment technologies (e.g. filtration, ultraviolet light, heat, ozone), either onboard vessels or through onshore facilities. The Parties should also facilitate research directed to studying the life cycles of alien species with the greatest potential for invading the Great Lakes basin ecosystem, including identification of their potential interactions with, and impacts on, indigenous aquatic species.

- Until acceptable long-term treatment technologies are developed for treating ballast water to achieve the binational discharge standards, the Commission should recommend that the Parties give serious consideration to chemical treatment of ballast water as a short-term, emergency measure for all vessels entering the Great Lakes from outside the Exclusive Economic Zone. To facilitate the short-term, emergency use of chemical treatment, the Commission should recommend that the Parties, in cooperation with shippers and other relevant stakeholders, undertake appropriate testing and evaluation activities to determine the efficacy of alternative chemicals, including effective biocide chemical dosages, relative costs, onboard handling requirements and vessel safety, and potential environmental impacts of treated ballast water discharges. The Parties should develop and apply a uniform protocol for evaluating the results from the testing and evaluation program for application throughout the Great Lakes basin.

- The Commission should recommend to the Parties that shippers and other relevant stakeholders immediately implement best management practices for ballast tank sediment control for all vessels entering the Great Lakes basin. The Commission should also recommend that the Parties undertake a program to publicly recognize the efforts of shippers engaged in good management practices.

- The Commission should recommend to the Parties that, as rapidly as possible, shippers incorporate vessel design modifications as appropriate for existing and new vessels, as a means of facilitating ballast water exchange on the open seas, and the effectiveness of other measures being considered (e.g. chemicals, filtration, ultraviolet light, heat) for treating ballast water to meet binational discharge standards. The Commission should also assist the Parties as appropriate in their interactions with the International Maritime Organization on the issue of vessel design modifications as a means of addressing the problem of alien invasive species in ballast water.

- The Commission should recommend that the Parties develop and implement effective contingency plans for responding to (i) the accidental discharge of untreated ballast water resulting from a collision or grounding of a vessel in the Great Lakes basin; (ii) the initial discovery of a new alien invasive species in the Great Lakes basin ecosystem; and (iii) the discovery of an alien invasive species in a region previously thought to be free of such organisms. The Commission should also recommend that the Parties clearly identify the responsible agencies and lines of authority for addressing alien invasive species in the Great Lakes basin, and ensure the information is readily available throughout the basin. Further, the Commission should recommend that the Parties facilitate systematic monitoring throughout the Great Lakes basin as a means of assessing the extent of current infestations, as well as facilitating early detection of new alien invasive species.

GREAT LAKES SCIENCE ADVISORY BOARD

The SAB recommends the following to the IJC:

2.1 Methodologies for Community Health Assessment: Measuring Injury to Health 37

- Recommend that the Parties establish prospective and retrospective registries of neurological deficits to identify subpopulations at risk from exposures to developmental toxicants.

- Recommend that the Parties establish institutional health structures at the local and regional level that can effectively investigate and respond to community health concerns that may be caused by chemical pollutants.

- Link human epidemiology to exposure data on air, water, sediments and biota in the preparation of future reports on Remedial Action Plans and Lakewide Management Plans.

- Recommend that the Parties facilitate the access of researchers to health information, while not compromising the rights of individuals to privacy and confidentiality.

- Recommend that the Parties make representations, with respect to pending legislation on the privacy and confidentiality of health information, to ensure that the capacity to monitor long-term trends in pollutant-induced diseases and disorders is not jeopardized.

- Recommend that the Parties develop a coordinated binational monitoring program to determine the incidence of health effects in wildlife that have been attributed to exposures to persistent toxic substances.

- Recommend that the Parties monitor the chemical exposures of human and wildlife populations using limits of detection appropriate to the known toxicology of these substances.

2.2 Protecting Human Health from Exposure to Contaminants in Great Lakes Fish 47

- Recommend to the Parties that the U.S. National Academy of Sciences and the Royal Society of Canada convene a binational committee to develop a uniform and consistent protocol to protect human health from contaminants in Great Lakes fish.

3.1 Review of Annex 1 of the Great Lakes Water Quality Agreement 52

- Recommend that the Parties initiate a transparent and inclusive process to revise Annex 1 to drive actions toward accomplishment of the Agreement's purpose.
- Recommend that the Parties, in conjunction with revisions to Annex 1, design and implement binationally harmonized monitoring and surveillance that will allow statistically credible judgments regarding achievement of the Specific Objectives.

3.2 Review of Agreement 58

- Recommend that the Parties conduct a review of the adequacy of the Agreement, given the evolving state of basin governance and the need for the Agreement and its institutions, to both adapt to and influence that evolution.

3.3 Nonpoint Sources of Pollution from Land-use Activities 58

- Recommend that the Parties quantify pollutant loadings to receiving waters by individual nonpoint source control practices, the nature and magnitude of associated impacts and the costs of control (and lack of control) of nonpoint source pollution.
- Recommend that the Parties adopt systematic methods to evaluate nonpoint source pollution control programs.
- Recommend that the Parties develop performance standards for non-point source pollution control technologies, including standards for the land surface.
- Recommend that the Parties to extend the use of economic incentives for the control of pollution from nonpoint sources.
- Recommend that the Parties adopt full-cost pricing of water and sewerage services, incorporating a scarcity value of the water and including provisions for infrastructure maintenance, upgrading and replacement.
- Recommend that the Parties review current institutional arrangements for water and watershed management, and explore the feasibility of collaborative, multi-stakeholder regional or watershed-based institutional structures.

3.4 Evaluation of SOLEC Indicators 63

- Evaluate the utility of SOLEC indicators to fulfill the reporting requirements under the Great Lakes Water Quality Agreement.
- Increase the IJC's emphasis on its role to assess the state of the lakes and evaluate progress under the Great Lakes Water Quality Agreement, now that a framework for indicators and reporting has been developed.

4.1 Application of a Methodological Framework and a Proposed Process for Agreement Institutions in Addressing Emerging Issues in Great Lakes Science, Research and Policy 70

- Direct a specific group to be responsible for organizing and managing a workshop to identify trends and emerging issues under the Great Lakes Water Quality Agreement at the beginning of each biennial cycle, report on the outcome of their work at each IJC biennial Public Forum, and consider the information when developing work plans for priority activities during each next biennial cycle.
- Direct the advisory institutions of the IJC, according to their roles relative to the science, research and policy relevance of an issue, to take a leading role in assessing those issues related to their mandate.

- Direct the advisory institutions to provide a regular report on emerging issues to the IJC, as part of their biennial reporting process under the Agreement.

4.2 Green Chemistry **72**

- Recommend that the Parties promote and coordinate research efforts and visibility of green chemistry priorities within their programs, and on a binational level, to promote the innovation and adoption of new technologies in the emerging field of green chemistry to Great Lakes industry.

COUNCIL OF GREAT LAKES RESEARCH MANAGERS

The Council recommends the following to the IJC:

3.3 Emerging Contaminants and Pharmaceuticals in Great Lakes Waters **96**

- Based on the information found in section 3.3 of the *1999-2001 Priorities and Progress under the Great Lakes Water Quality Agreement*, recommend to the Parties that the following areas of research and action be implemented regarding emerging contaminants and pharmaceuticals in Great Lakes water:
  a. examine inputs to and outputs from wastewater and drinking water treatment plants to determine if emerging contaminants are present;
  b. determine the effective levels, biotic indicators and degradation times for the emerging contaminants; and
  c. identify viable options for wastewater and drinking water treatment plants to remove those chemicals identified as potential threats to human health and the ecosystem.

3.4 Understanding the Interaction of Ground Water and Surface Water in the Great Lakes Basin **102**

- Recommend to the Parties that the highest priority research funding be directed to the following ground water research needs listed in priority order:
  a. research on the effects of land-use changes and population growth on ground water availability and quality;
  b. development on a comprehensive description of the role of ground water in supporting ecological systems;
  c. development of improved estimates that reliably reflect the true level and extent of consumptive use; and
  d. esearch on ground water discharge to surface water streams and to the Great Lakes, and a systematic estimation of natural recharge areas.

3.5 Understanding the Long-term Impacts of Water Level Fluctuations, Diversions and Consumptive Uses in the Great Lakes - St. Lawrence River System **105**

- Recommend to the Parties that the following broad areas of research and action be implemented as they pertain to Great Lakes water quality:
  a. research the effects of climate change and develop a simulation of Great Lakes watershed hydrology;
  b. develop research needs for wetlands;
  c. research coastal development including the evaluation of riparian shore properties and impacts of increased dredging;
  d. research the human ability to regulate water levels and assessments of long-term impacts of water level fluctuations on ecosystem integrity; and
  e. develop a common database for environmental and shoreline interests, water uses and better tools to project future uses.

3.6 Alien Invasive Species Research **108**

- Recommend that the Parties place an emphasis on the immediate implementation of current AIS research recommendations proposed by the Great Lakes Water Quality Board and other advisory panels.

- Recommend that the Parties give priority support and funding to well-focused, applied research needed to establish ballast water discharge standards and prevent new introductions of AIS.

- Recommend that the Parties provide resources for a binational coordination of efforts to ensure that a mutually acceptable ballast water discharge standard is developed and that unnecessary duplication of efforts is eliminated.

INTERNATIONAL AIR QUALITY ADVISORY BOARD

The IAQAB recommends the following to the IJC:

4.6.2 Sources and Loadings **151**

There is a clear need to place the relative loading of persistent toxic substances from atmospheric deposition in context with the loading of these substances from all pathways to Lake Michigan and the other Great Lakes.

- Recommend to the Parties that the completion of the Lake Michigan Mass Balance Study for all pathways is crucial to development of an effective control strategy and that U.S. EPA should expedite its prompt conclusion.

The Lake Michigan Mass Balance Study targets only four pollutants. At the present time, little information is available regarding the relative importance of atmospheric deposition to the loadings of other pollutants to Lake Michigan, or for essentially all pollutants of concern to the other Great Lakes.

- Recommend to the Parties that basic mass balance information should be developed for other pollutants of concern in Lake Michigan, as well as pollutants of concern in other lakes.

Current emission inventories must be improved and extended to areal sources if more precise model outputs and an effective control strategy are to be developed.

- Recommend to the Parties that the following immediate actions be taken.

  a. For dioxin, review and compare the Great Lakes Air Toxics Emissions Inventory and the inventory developed by Dr. Cohen, with the goal of improving the dioxin inventory for the region, particularly for major point sources. The enhancement of emission factors, other parameters necessary to modeling, and production or process data should be significant elements of this effort. Specific to Lake Michigan, emissions from major sources within 100 km of the basin should be confirmed, preferably by a combination of source testing and data quality review.

  b. Support further quantification of dioxin emissions associated with backyard residential waste burning, including refinement of areal emission factors and determination of the extent of this practice on a regional basis.

  c. For a number of persistent toxics, including PCBs, chlordane, mercury and critical banned pesticides, perform a review of current and historical land-use records, along with targeted modeling and monitoring at urban centres using one or more of the techniques presented at the November 2000, IAQAB workshop in Milwaukee, Wisconsin to estimate potential areal loadings.

d. Undertake an air toxics monitoring and measurement program designed to identify open sources of PCBs, such as contaminated brownfield and storage and waste management sites. This monitoring program should have a mobile capability with simplified procedures for deployment and relocation, as well as for upwind and downwind studies or measurements. All measurements should be coordinated with modeling predictions. Immediate priority should be given to estimating emissions from individual landfills, wastewater sludge drying operations and open transformer storage facilities for inclusion in the inventory. Measurement of other banned contaminants should also accompany such programs, as feasible.

4.6.2 Modeling **152**

- Recommend to the Parties that the models and strategies for Lake Michigan and its related urban area of Chicago, reviewed at the workshops, should be developed further and their application extended to other urban areas and other lakes within and outside the Great Lakes basin.

- Recommend to the Parties, that as a first step, the adequacy of information on contaminant physical and chemical properties, as well as available emissions and ambient concentration data, should be determined prior to any modeling application.

- Recommend to the Parties that the Lake Michigan Mass Balance dataset, including available sample extracts and related measurements, and appropriate model(s), be used for the prediction of the sources and transport of other air toxics, such as polycyclic aromatic hydrocarbons (PAHs), beyond the original LMMB target compounds of mercury, PCBs, trans-nonachlor and atrazine.

- Recommend that the Parties explore the application of other multimedia non-steady state models as an effective method of determining the longer term trends in the deposition of persistent toxic substances to the Great Lakes.

- Recommend that the Parties apply models for pesticide volatilization from soils to fields within and outside the Great Lakes basin where significant concentrations of banned pesticide residuals are detected, both to estimate the possible contribution of continued cultivation and to develop a code of best practice for such areas.

- Recommend that the parties begin a predictive modeling effort to identify regions around the Great Lakes for which there is a high probability of substantial emissions of persistent toxics. Derivation and verification of any such modeling technique should be focused initially in major urban areas.

4.6.2 Ambient Sampling **152**

- Recommend that the Parties continue ambient air sampling over the surface of the lake to provide better estimates of representative regional concentrations of these pollutants and improve the characterization of their air/water exchange.

- Given the regional designation of the Sleeping Bear Dunes IADN ambient monitoring site, recommend that the Parties interpret data collected at this site with assistance from atmospheric models that address air/surface dynamics and include meteorological models.

- Ensure that any modeling effort be supported by adequate ambient measurements to provide verification for any model output.

4.6.2 Source Control Initiatives **152**

- The recently completed Delta Institute Lake Michigan Regional Air Toxics Stratgegy identifies linkages and opportunities for further air toxics reductions via various, ongoing, specific programs and initiatives under state and U.S. federal legislation. The IJC, through their relevant advisory boards, should review this proposed strategy and comment on its applicability to deposition reductions in the Lake Michigan and other Great Lakes basins from a binational perspective.

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Chapter 1

The Great Lakes Water Quality Board

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1.1 INTRODUCTION

The Great Lakes Water Quality Agreement identifies the Great Lakes Water Quality Board (WQB) as the principal advisor to the International Joint Commission (IJC) on all issues related to the water quality of the Great Lakes system. Consistent with this mandated role, the WQB focused on two priority issues during 1999-2001: 1. alien invasive species and biological pollution of the Great Lakes basin ecosystem, and 2. progress made by the Parties under the Binational Toxics Strategy to virtually eliminate persistent toxic substances.

The WQB also assisted the Parties with specific procedures and activities for addressing Lakewide Management Plans (LaMPs) and Remedial Action Plans (RAPs). Further, the IJC requested advice from the WQB regarding reporting responsibilities concerning RAPs and LaMPs under the changing dynamics of governments.

A related WQB activity was consideration of the proposed criteria for the removal of the Area of Concern (AOC) designation, consistent with the restoration of beneficial water uses as outlined in the Agreement. A particular interest was designation of the appropriate status for AOCs that have completed RAP implementation, but require additional time for remedial actions to ensure the restoration of previously-impaired water uses.

In collaboration with the IJC's International Air Quality Advisory Board, the WQB convened a workshop to evaluate the adequacy of the U.S. and Canadian legal frameworks for addressing atmospheric deposition of toxic pollutants into the Great Lakes basin. The workshop provided valuable insight into how to assess legal components of an environmental issue of concern to both Parties.

The full text of WQB reports can be found at http://www.ijc.org/boards/wqb.

1.2 ALIEN INVASIVE SPECIES AND BIOLOGICAL POLLUTION OF THE GREAT LAKES BASIN ECOSYSTEM

1.2.1 Introduction

Alien invasive species are organisms that move, or are accidentally or intentionally transported, from their original location to another location and, in the absence of their natural controls (e.g. predators, pathogens, environmental conditions), can grow unabated resulting in significant environmental and economic consequences. The Great Lakes basin has been particularly hard hit in recent decades by the accidental or unintentional introduction of alien or nonindigenous organisms from distant locations. Serious potential exists for additional species to become successfully established in the basin, causing major alterations in the native plant and animal species, existing food webs, and possibly destroying indigenous populations. After habitat destruction, alien invasive species are the second leading cause of the extinction of native aquatic species.

Since the early 1800s, the Great Lakes have been invaded by a succession of alien species, causing environmental havoc, interfering with beneficial human water uses (e.g. drinking water, irrigation, hydropower, recreation) and costing billions of dollars to control. The pace of introductions has accelerated since the 1959 opening of the St. Lawrence Seaway. At least 70 percent of the nonindigenous aquatic species discovered in the Great Lakes since 1985 are native to freshwater and brackish water systems in other parts of the world, particularly the Black, Caspian and Azov seas of Eastern Europe.

Alien aquatic organisms that have successfully invaded the Great Lakes basin ecosystem since 1985 include the zebra mussel, eurasian ruffe, round goby and the fishhook waterflea. In addition to displacing indigenous mussel populations, the zebra mussel attaches itself to hard submerged surfaces and forms densely-layered colonies that can readily clog intake structures of drinking water facilities, irrigation systems and hydropower plants. The eurasian ruffe and round goby can feed on native fish eggs and young, as well as compete with native fish populations for available food supplies. The tiny fishhook waterflea can achieve high population densities, and has gained notoriety by forming large 'clumps' that can entangle fishing lines.

Multiple potential sources for alien species to enter the Great Lakes basin include: 1. ballast water discharges from ships; 2. transport in canal and diversion water flows; 3. discard of alien species used as live bait; 4. escape from aquaculture activities; 5. gardening or horticulture of alien species; 6. discharge or escape from aquaria and ornamental ponds; 7. sale and use of live alien species as food organisms; 8. creation of transgenic organisms; and 9. discharge or escape from research and educational facilities. The WQB has identified the discharge of ballast water from ships coming to the Great Lakes basin from outside the U.S. and Canadian 200-nautical mile Economic Exclusion Zone as the most important source. The taking on of ballast water is a long-standing practice in the shipping industry, as a means of enhancing the safety of ship operation by increasing vessel stability and maneuverability.

The problem arises because living aquatic organisms may be pumped aboard a vessel as its takes on ballast water. They can survive in the ballast tanks and be transported long distances from their original source. If conditions at the location where the ballast water is discharged are conducive to the growth and reproduction, these organisms can quickly become established at the new location.

About 10 billion tons of ballast water is transported around the world each year, with an estimated 3,000 species being transported in ballast water on any given day. Of significance to the Great Lakes is the fact that approximately 500 to 600 foreign flag vessels routinely enter the basin each year from ports outside the Economic Exclusion Zone . . .

The number and types of aquatic organisms carried in ballast water can be substantial. As one example, 367 species of living animals and plants were identified in the ballast water of a single ship traveling between Japan and the United States. About 10 billion tons of ballast water is transported around the world each year, with an estimated 3,000 species being transported in ballast water on any given day. Of significance to the Great Lakes is the fact that approximately 500 to 600 foreign flag vessels routinely enter the basin each year from ports outside the Economic Exclusion Zone, increasing the chance of unintentional introductions of alien invasive species via their ballast water discharges.

With some clear exceptions, ballasted vessels entering the Great Lakes basin from outside the Economic Exclusion Zone must exchange their ballast water outside the 200 nautical-mile limit, ideally in water at least 2000 meters deep. However, open-sea ballast water exchange is not completely effective in preventing the spread of alien invasive species, largely because 100 percent exchange of the ballast water cannot be guaranteed.

More problematic is the fact that approximately 80 percent of the vessels entering the Great Lakes report 'no ballast on board' (NOBOB) because they are carrying cargo. Such vessels are exempt from the mandatory ballast water exchange testing and enforcement actions currently required of vessels entering the Great Lakes, even though they can typically contain a significant residual quantity of unpumpable ballast water and sediment, estimated to range between 50 and 450 tonnes per ship. As its cargo is unloaded, a NOBOB vessel will take on ballast water, which mixes with this residual ballast contained in its tanks. When taking on new cargo, the vessel will discharge the ballast water mixture, including living aquatic organisms contained in it.

1.2.2 Treatment Options for Ballast Water

Alternatives to address alien invasive species in ballast water include reducing species taken on board; retaining ballast water on board; exchanging ballast water at sea; treating ballast water onboard ships; and treating ballast water in onshore facilities. All have their particular strengths and weaknesses.

The primary option is to exchange the ballast water on the open seas. The internal configuration of most ballast tanks, however, ensures that complete exchange of the ballast water cannot be ensured.

Onboard ship methods for attempting to control alien invasive species include filtration of incoming ballast water and onboard disinfection of ballast water. The former typically must be accompanied by additional treatment to ensure all aquatic organisms are addressed. These can include biocides, ultraviolet light, heat and ozone. Common problems with these alternatives include determination of their effectiveness under different vessel operating conditions, their overall economic costs, and the safety of crews and shipping vessels.

Another approach is to retain the ballast water onboard vessels during their passage within the Great Lakes basin. Restricting a ship from discharging ballast water, however, also restricts its maximum cargo load, with economic consequences. Another possibility is to discharge the ballast water to onshore treatment facilities. There are presently few onshore facilities in the Great Lakes capable of handling the large volumes of ballast water.

1.2.3 Recommendations for Addressing Ballast Water Discharges as a Source of Alien Invasive Species in the Great Lakes Basin

The WQB believes a comprehensive, preventative binational approach is fundamental for an expeditious, efficient and cost-effective solution to the problem. A preventative approach is always preferable to a reactive approach, since it invariably costs less over the long term to prevent problems than to attempt to treat them after they have occurred. Unlike water pollution, successful invasions of alien aquatic species are very difficult to clean up.
Given the magnitude and economic importance of the Great Lakes shipping industry, a mix of measures may ultimately be required to adequately address the issue of ballast water and alien invasive species. To this end, the WQB offers several recommendations to the IJC.

Binational Ballast Water Discharge Standards

The most direct way to protect the Great Lakes from alien invasive species via ballast water is to develop and enforce binational ballast water discharge standards for all vessels discharging ballast water within the Great Lakes basin. Effective application and enforcement of binational ballast water discharge standards will go a long way to ensure that alien invasive species in discharged ballast water do not become established in the basin. To this end, the WQB also awaits the outcome of the work of the Ballast Water and Shipping Committee of the U.S. federal Aquatic Nuisance Species Task Force in developing a realistic standard for ballast water discharges.

- **As the core of a preventative, binational approach for addressing the serious threat of alien invasive species in the Great Lakes basin, the Commission should recommend to the Parties that effective binational ballast water discharge standards be developed, implemented and enforced throughout the Great Lakes basin as rapidly as possible. Further, the Commission should recommend the Parties prohibit the discharge of ballast water of any type into the Great Lakes basin from ballasted vessels and from vessels reporting no ballast on board (NOBOB), whatever their origin, that do not meet the binational standards while they are within the Great Lakes basin.**

Technologies to Achieve Ballast Water Discharge Standards

To expeditiously implement and enforce effective ballast water discharge standards, additional resources should immediately be directed to evaluating alternative long-term ballast water treatment technologies. Additional knowledge on the life cycles of alien species that have invaded, or may invade, the Great Lakes basin ecosystem also is urgently needed to assist in identifying the stage in the life cycle most vulnerable to prevention and/or control technologies. Also important are accurate data and information on the potential interactions between alien and indigenous species, and how this may facilitate successful invasions.

- **To aid in achieving the binational ballast water discharge standards, the Commission should recommend that the Parties, in cooperation with shippers and other relevant stakeholders, facilitate an immediate and significant investment in resources directed to the development of effective, long-term ballast water treatment technologies (e.g. filtration, ultraviolet light, heat, ozone), either onboard vessels or through onshore facilities. The Parties should also facilitate research directed to studying the life cycles of alien species with the greatest potential for invading the Great Lakes basin ecosystem, including identification of their potential interactions with, and impacts on, indigenous aquatic species.**

Even with fast-track evaluation of alternative control technologies, the threat of successful infestations of the Great Lakes basin ecosystem by alien species continues. Thus, the WQB believes that governments should also consider the interim use of chemical treatment on a ***short-term, emergency basis*** to combat the spread of alien invasive species via ballast water discharges. This approach should include immediate implementation of testing and evaluation to identify the most reliable candidate chemicals and their required dosages, their relative costs and effectiveness under different vessel operating conditions, onboard handling and safety concerns, and the potential environmental impacts of treated ballast water discharges, and should include ship-scale pilot testing and evaluation. Governments also should ensure a uniform protocol for evaluating these testing and evaluation activities.

- **Until acceptable long-term treatment technologies are developed for treating ballast water to achieve the binational discharge standards, the Commission should recommend that the Parties give serious consideration to chemical treatment of ballast water as a short-term, emergency measure for all vessels entering the Great Lakes from outside the Exclusive Economic Zone. To facilitate the short-term, emergency use of chemical treatment, the Commission should recommend that the Parties, in cooperation with shippers and other relevant stakeholders, undertake appropriate testing and evaluation activities to determine the efficacy of alternative chemicals, including effective biocide chemical dosages, relative costs, onboard handling requirements and vessel safety, and potential environmental impacts of treated ballast water discharges. The Parties should develop and apply a uniform protocol for evaluating the results from the testing and evaluation program for application throughout the Great Lakes basin.**

Best Management Practices for Ballast Tank Sediment Control

Sediment in ballast tanks can interfere with the technologies being evaluated for treating ballast water, thereby hindering the successful development of binational ballast water discharge standards. The WQB believes that implementation of best management practices for ballast tank sediment would facilitate achievement of these standards. Vessels employing sediment best management practices are also more likely to be amenable to implementing effective measures for treating ballast water. Because implementing sediment best management practices is a positive action on the part of shippers, the WQB also believes that governments should publicly recognize such actions, as a positive incentive for emulation throughout the Great Lakes basin and elsewhere.

- **The Commission should recommend to the Parties that shippers and other relevant stakeholders immediately implement best management practices for ballast tank sediment control for all vessels entering the Great Lakes basin. The Commission should also recommend that the Parties undertake a program to publicly recognize the efforts of shippers engaged in good management practices.**

Shipping Vessel Design Modifications

Involvement of the shipping industry in addressing this problem is essential. The WQB supports the principle of allowing shippers flexibility regarding the methods to be employed to address alien invasive species and ballast water discharges, including the particular role of NOBOB vessels. Ship design is an important consideration for enhancing the efficacy of the alternative technologies for treating ballast water, and can also facilitate effective application of new technologies for disinfecting ballast water, both for existing and future vessels.

- **The Commission should recommend to the Parties that, as rapidly as possible, shippers incorporate vessel design modifications as appropriate for existing and new vessels, as a means of facilitating ballast water exchange on the open seas, and the effectiveness of other measures being considered (e.g. chemicals, filtration, ultraviolet light, heat) for treating ballast water to meet binational discharge standards. The Commission should also assist the Parties as appropriate in their interactions with the International Maritime Organization on the issue of vessel design modifications as a means of addressing the problem of alien invasive species in ballast water.**

Contingency Plans for Alien Invasive Species

Many efforts by governments, shippers and environmental non-governmental organizations (ENGOs) to address the problem of alien invasive species in the Great Lakes basin are characterized by differing goals, programs, resources and timetables. The result is inconsistent and unharmonized actions. Equally problematic is inadequate guidance regarding the myriad of agencies addressing different aspects of this problem, as well as the multiple commissions, panels and ENGOs involved in it.

Also lacking is systematic monitoring for alien invasive species in the basin. Further, clear procedures and lines of responsibility must be identified for appropriate discovery, response and enforcement actions. It is a logical step, therefore, to ensure emergency situations involving alien invasive species are handled with the same priority as discharges of oil and hazardous polluting substances, as highlighted in Annexes 5, 6 and 9 of the Agreement.

- **The Commission should recommend that the Parties develop and implement effective contingency plans for responding to (i) the accidental discharge of untreated ballast water resulting from a collision or grounding of a vessel in the Great Lakes basin; (ii) the initial discovery of a new alien invasive species in the Great Lakes basin ecosystem; and (iii) the discovery of an alien invasive species in a region previously thought to be free of such organisms. The Commission should also recommend that the Parties clearly identify the responsible agencies and lines of authority for addressing alien invasive species in the Great Lakes basin, and ensure the information is readily available throughout the basin. Further, the Commission should recommend that the Parties facilitate systematic monitoring throughout the Great Lakes basin as a means of assessing the extent of current infestations, as well as facilitating early detection of new alien invasive species.**

1.3 GREAT LAKES BINATIONAL TOXICS STRATEGY

1.3.1 Introduction

The negative effects of toxic substances on wildlife in the Great Lakes basin was one impetus for development of the 1972 Agreement. The Agreement was broadened in 1978 to encompass an ecosystem approach, including consideration of the interactions of air, water and all living organisms, including humans. It also called for the virtual elimination of the input of persistent toxic substances into the Great Lakes. The 1987 Protocol to the Agreement placed even greater emphasis on addressing persistent toxic substances.

1.3.2 The Strategy

In spite of significant improvements over the last two decades, persistent toxic substances are still present in the Great Lakes basin ecosystem. Therefore, on April 7, 1997, the Parties signed the Great Lakes Binational Toxics Strategy. The purpose of the strategy:

"... is to set forth a collaborative process by which Environment Canada (EC) and the United States Environmental Protection Agency (USEPA), in consultation with other federal departments and agencies, Great Lakes states, the Province of Ontario, Tribes, and First Nations, will work in cooperation with their public and private partners toward the goal of virtual elimination of persistent toxic substances resulting from human activity, particularly those which bioaccumulate, from the Great Lakes Basin, so as to protect and ensure the health and integrity of the Great Lakes ecosystem. ... An underlying tenet of this Strategy is that governments cannot by their actions alone achieve the goal of virtual elimination. This Strategy challenges all sectors of society to participate and cooperate to ensure success."

1.3.3 Progress Review Work Group

Recognizing the serious nature of toxic chemical contamination of the Great Lakes basin ecosystem, the IJC asked the WQB in December 1999 to assess progress made under the Binational Toxics Strategy, including the contribution of the strategy toward achieving the Agreement's virtual elimination goal. To carry out this task, the WQB convened a Progress Review Work Group, comprised of WQB members and individuals from a cross-section of Great Lakes basin governments, academia, industry and ENGOs.

The work group structured its review around the purpose of the Strategy ("to set forth a collaborative process"); its four primary steps (information gathering; analysis of current regulations, initiatives and programs which manage or control substances; identification of cost-effective options to achieve further toxic pollutant load reductions; implementation of actions to work toward the goal of virtual elimination); and the specific challenges of the strategy.

The work group undertook a quantitative and qualitative assessment. The quantitative component involved review of existing data, records and information on the amounts of contaminants currently entering the Great Lakes from sources both within and outside its basin. The qualitative component comprised in-depth interviews with a cross-section of the Great Lakes community, including representatives of federal, state, provincial and municipal governments, business and industry, and ENGOs. The output will be advice to the WQB on several issues which include the following.

- Assessment of the contributions of the strategy toward achievement of the Agreement's virtual elimination goal, including how well the Binational Toxics Strategy is being implemented, particularly in regard to meeting each of its challenges, how well each of the strategy's four steps is being done and how useful each step is.
- Confirmation of whether or not sufficient quantitative information is available to substantiate whether each of the strategy's challenges is being met and, if not, to identify the gaps and possibilities for obtaining the needed information.
- Advice and guidance for enhancing the contribution and efficiency of the strategy toward achieving the Agreement's virtual elimination goal.
- Identification of additional challenges the strategy could undertake to fill gaps in the range of virtual elimination initiatives.

Conclusions and recommendations will be published separately.

1.4 LEGAL WORKSHOP ON PROTECTION OF GREAT LAKES WATER QUALITY FROM ATMOSPHERIC DEPOSITION OF CONTAMINANTS

1.4.1 Introduction

Annex 15 of the Agreement focuses on the atmosphere as a significant pathway for toxic substances entering the Great Lakes basin. To assist the IJC in reviewing and assessing the Parties' programs and progress with regard to airborne toxic substances, the WQB and the International Air Quality Advisory Board jointly convened a workshop that focused on the legal framework in the United States and Canada to address atmospheric deposition. The workshop proceedings are available at http://www.ijc.org/boards/iaqab/protect.html A summary is provided below.

The workshop was held in an animated, interactive setting resembling a 'moot court,' in an environment of mutual trust and respect. A primary goal was to enhance the awareness of legal issues related to protecting Great Lakes water quality from atmospheric deposition of persistent toxic substances arising from human activities.

1.4.2 The Workshop

The workshop, held at the University of Windsor on October 26-27, 1999, addressed the question:

What legal tools are available, under current Canadian and United States law, to control atmospheric deposition of persistent toxic substances to the Great Lakes originating from sources within and outside the basin?

The workshop was held in an animated, interactive setting resembling a 'moot court,' in an environment of mutual trust and respect. A primary goal was to enhance the awareness of legal issues related to protecting Great Lakes water quality from atmospheric deposition of persistent toxic substances arising from human activities. It was designed to provide a fact-finding environment for identifying and demonstrating legal tools that could mitigate atmospheric deposition of contaminants. To explore the issue, three hypothetical scenarios were developed, recognizing the distinct regulatory structure in each country.

- The **technical scenario**, constructed primarily from "real world" information, described a hypothetical lake that might be adversely impacted by mercury emissions from a proposed new source located near the shore. It underpinned both the U.S. and Canadian legal scenarios.

- Under the **United States legal scenario**, a permit was to be issued to a new air emission source, and an ENGO had filed suit against the source for potential violation of environmental protection laws. The scenario was constructed under U.S. federal and Michigan state laws.

- Under the **Canadian legal scenario**, a Certificate of Approval was issued by the Ontario Ministry of the Environment for a new air emission source. The mercury emission limit in the Certificate was challenged by the source, and an ENGO was granted intervention status.

The existing permitting process under the prevailing regulatory structure in each country was used as the basis for addressing the scenarios. A workshop panel provided reactions to the various legal arguments, with all participants engaged in open discussions on the scenarios and conclusions.

1.4.3 Key Findings

Based on written briefs and oral arguments, the panel answered two specific questions regarding the adequacy of the U.S. and Canadian legal framework to address airborne pollutants.

Canada

1. *Does the Canadian legislative framework allow Canada to effectively address the problem of water pollution via the atmosphere?*

The answer was a qualified 'yes.' The combination of federal and provincial frameworks is patchy, not comprehensive, and frequently appears to be both *ad hoc* and subjective in nature.

2. *Does Canada's domestic legislative framework provide for effective fulfillment of its international obligations?*

The answer was a qualified 'no,' noting that the framework was not sufficiently prescriptive.

United States

1. *Does the United States legislative framework allow the United States to effectively address the problem of water pollution via the atmosphere?*

The answer was a qualified 'yes,' noting that Section 112 of the Clean Air Act was adequate. A more aggressive and creative approach, however, is required for application of the framework.

2. *Does the United States' domestic legislative framework provide for effective fulfillment of its international obligations?*

The answer was that there is a disconnect between the U.S. legislative framework and its international commitment to virtual elimination, specifically in the definition of the goal. If virtual elimination was defined as absence of harm (i.e. removal of fish-consumption advisories), the answer was a qualified 'yes.' If virtual elimination was defined as zero discharge, the answer was a qualified 'no.'

1.4.4 Other Key Issues

- Fulfillment of Agreement Requirements — To ascertain whether programs are on track to meet the requirements of the Agreement, particularly Annex 15, the underlying science must be improved and air and water monitoring programs expanded.

- The Science — The technical challenges associated with linking pollutant sources and loads for a particular waterbody must be better addressed, including ensuring that the work of the scientific community appropriately informs policymakers. Where pollutant emission reductions are required, linking atmospheric depositions to their individual sources can proceed in parallel with work to ensure the institutional framework needed to achieve these reductions is adequate.

- Total Maximum Daily Load — The TMDL process under the U.S. Clean Water Act offers promise as a legal authority and a conceptual approach for addressing atmospheric deposition of contaminants to a waterbody. However, the time frame to implement the process, as well as to realize environmental improvements, is too lengthy. Appropriate legal and institutional frameworks must be developed in a more timely manner.

- Virtual Elimination and Precaution — The concept of virtual elimination for persistent toxic substances is reflected in domestic federal legislation in both Canada and the United States, as well as in the Agreement. Both countries have ascribed to the precautionary principle. However, both countries also need to more explicitly incorporate virtual elimination and precaution into their domestic programs and decision-making processes. Further, they need to better align existing legislative and institutional frameworks and better use their authorities to help meet their international obligations.

- Other Legal Authorities — The U.S. discussions were based on selected provisions of the Clean Air Act and the Clean Water Act. Other sections of the Clean Air Act should be explored as additional tools to protect water quality from atmospheric contaminant deposition. Further, U.S. states have the option of exercising their independent sovereign authority to act or regulate in the area of toxic air deposition as a means of accounting for persistent, bioaccumulative toxic substances and for multiple exposure pathways.

1.5 REMEDIAL ACTION PLANS

1.5.1 Introduction

The 42 AOCs in the Great Lakes basin require restoration of beneficial water uses and protection of water supplies, recreation and aquatic life. Based on requirements outlined in the Agreement, the Parties, in cooperation with the state and provincial governments, have been developing RAPs for each AOC. RAPs are submitted to the IJC for review and comment. One continuing goal of the WQB is to assist the IJC in enhancing the confidence of RAP committees that the IJC will conscientiously review progress to date in addressing AOCs. To this end, the WQB formulated a protocol for responding to the conclusions and recommendations submitted from RAP committees. This protocol, provided below, illustrates the intended actions and responses of the WQB to future RAP submissions.

During the 1999-2001 biennial work cycle, the WQB participated in a RAP public workshop on monitoring and management in the Toronto, Ontario AOC and in a public meeting in the Waukegan, Illinois AOC.

1.5.2 Public Workshop on Watershed Monitoring and Management — Toronto, Ontario

On May 13, 1999, the Toronto and Region RAP's two coordinating agencies, the Waterfront Regeneration Trust and the Toronto and Region Conservation Authority, along with the WQB, held a public workshop on watershed monitoring and management. The purpose was to:

- learn about and discuss a proposed monitoring framework to provide the necessary information for assessing the health of watershed ecosystem progress toward restoring beneficial uses, and to provide guidance for making management decisions;
- use facilitated breakout sessions to obtain feedback on the adequacy and practicality of the proposed monitoring framework and innovative monitoring approaches;
- learn about and discuss recent advances in data interpretation tools to assist in making sediment management decisions; and
- provide advice on how the WQB and the IJC can assist in bringing these issues to the attention of the federal and provincial governments.

Preparatory Activities

To prepare for the workshop, a pre-meeting comprising over 30 local stakeholders was held April 12, 1999. Preliminary recommendations for restoring beneficial water uses within the Toronto AOC were developed, as follows:

- The IJC and its WQB advocate for the development of an "urban runoff annex" to the Agreement and ensure that priority be given to assisting local municipalities, agencies and others with storm water management infrastructure funding, research and monitoring.
- The IJC, its WQB, and its International Air Quality Advisory Board accelerate their joint efforts to address the issue of airborne pollutant deposition within the Great Lakes basin recognizing that the issue cannot be resolved through local community action.
- The IJC and its WQB encourage program development and federal funding for environmental education and awareness, stressing new approaches such as community-based social marketing to foster personal behavior change and ensure that support be focused on innovative partnerships with school boards, other agencies and community-based groups for effective delivery at the local level.
- The WQB, through the IJC, foster the sharing of timely information on cost and ecologically-effective technologies and creative solutions for addressing common causes of use impairments among "like" AOCs.

A series of focus group consultations also helped facilitate development of the proposed watershed monitoring framework. Consultations included staff from local and regional municipalities, government agencies, academics, consultants and interest groups.

Public Workshop

The May 13, 1999, public workshop included a range of discussions on the status and progress of the Toronto and Region RAP. In addition to discussing the proposed watershed monitoring framework and strategy, facilitated round-table sessions were used to generate public discussion and obtain feedback from all participants. The discussions focused on: 1. monitoring indicators; 2. the process for developing the monitoring framework; 3. main issues in developing and implementing the monitoring network; and 4. the potential role of the WQB and IJC in facilitating successful implementation of a watershed monitoring network.

Key Findings

Key findings are as follows.

- There was strong support for establishment of an interagency monitoring network within the Toronto Region. It was felt that a coordinating monitoring network would help eliminate duplication and ensure that funds were spent more effectively on monitoring activities.

- There was recognition of the need for monitoring data to be linked to watershed stresses / causes and the appropriate management actions required to solve problems that arise. Workshop participants felt that the results of monitoring must eventually lead to management actions in a process of continuous improvement.

- The process of developing the monitoring framework should be inclusive, not exclusive. Consultation should include agencies, municipalities, non-government organizations, industry, academics, consultants, and the public.

- In AOCs that contain significant urban development, surface runoff from developed areas can be the most significant source of poor water quality and impairment of beneficial uses. The WQB and the IJC should advocate for the development of an urban / storm water runoff annex to the Agreement.

- There needs to be a role for the public and educational institutions in collecting monitoring data. "Grass roots" involvement will be important in smaller specific monitoring projects and in developing support for larger monitoring activities.

- Based on the importance of monitoring to good decision-making and the trend in recent years to reduced budgets and subsequently, reduced monitoring activities, the WQB and the IJC should take a leadership role in emphasizing the need to secure long-term funding and expertise from the provincial and federal government for watershed-based monitoring.

1.5.3 Public Meeting on Remedial Action Plan — Waukegan, Illinois

Primary land uses in the Waukegan AOC are industrial, commercial and municipal, with some open and vacant lands. Designation as an AOC was based on the discovery of high levels of PCBs in the harbor sediment. Because of this contaminant, the harbor was among the first sites included on the National Priorities List after passage of the U.S. Superfund law in 1980. Beneficial water uses that were impaired because of the presence of PCBs included fish consumption restrictions, degradation of benthic, phytoplankton and zooplankton populations, dredging restrictions, beach closings, and loss of fish and wildlife habitat.

Initial Cleanup Efforts

Initial cleanup efforts for Waukegan Harbor sediments occurred from 1990 to 1993, with the focus on: 1. conversion of the harbor slip into a containment cell; 2. construction of a new slip to replace the converted one; 3. hydraulic dredging and removal of contaminated sediment; and 4. thermal extraction of PCBs from the sediment. Primary attention focused on remediation to reduce the PCB burden in the harbor sediment via dredging. Even with completion of the Waukegan Inner Harbor Project in June 1992, there was continued concern with residual PCBs as cleanup efforts did not address all the contaminated sediment in the harbor.

RAP Public Meeting Recommendations

The WQB convened a public meeting of the Waukegan RAP on May 11-12, 2000. Based on the meeting discussions, and in recognition of the large Hispanic community within this AOC, the RAP Committee developed recommendations, as follows:

- Governments should make greater efforts to achieve suitable outreach to the Hispanic community in the Waukegan area.
- Existing fish consumption advisories should be translated into Spanish and made widely available throughout the Hispanic community in the Waukegan area.
- Because the current inability to dredge portions of Waukegan Harbor has resulted in economic impacts to businesses in Waukegan, economic impacts should be quantified and used as additional rationale for considering dredging of the harbor.
- To maximize the exchange of information concerning dredging and environmental protection, the Waukegan Citizen's Advisory Group should explore partnerships with similar groups outside the basin.
- State and federal agencies should be engaged in Citizen's Advisory Group activities to the maximum extent.

The Waukegan Citizen's Advisory Group proposed a partnership with the Lake Baikal Ecological Network, a nonprofit conservation organization in Irkutsk, Russia. The partnership would 1. develop and exchange information on successful processes for effecting and maintaining clean water resources; 2. establish and sustain methods for developing and sharing educational materials and programs for effecting and maintaining clean water resources; 3. establish and sustain methods for developing and sharing technologies for clean water resources; and 4. create a data bank of watershed protection methods, materials and research activities currently in place for both lakes.

The Waukegan Citizen's Advisory Group proposed a partnership with the Lake Baikal Ecological Network, a nonprofit conservation organization in Irkutsk, Russia.

1.5.4 Protocol for Responding to RAPs Submitted to the WQB and the IJC

The WQB undertakes at least one public session per year at AOC locations throughout the Great Lakes basin. The objective is to engage local RAP groups in a dialogue about the Great Lakes and ongoing clean up efforts, and to encourage feedback to its boards and/or the IJC on issues of common concern. As a result, over the past few years the WQB has met with local RAP groups, held RAP-related workshops or open houses, and taken inspection tours of RAP areas familiarizing the IJC and its boards with the issues faced by local RAP groups and allowing for RAP committee interactions with the IJC Commissioners and staff and WQB members.

When local RAP groups offer suggestions and recommendations to the IJC, it is important to ensure that there is a conscientious effort on the part of the IJC to acknowledge and appropriately consider them. To ensure that appropriate acknowledgment and follow-up take place in response to submissions arising from RAP public meetings, the WQB prepared the following protocol.

Proposed Protocol

- If RAP public meeting submissions are forwarded to the IJC through the WQB, the WQB Secretary will formally acknowledge receipt of the RAP submission.
- The WQB will review and discuss the submission at its subsequent meeting and determine if it will provide any accompanying conclusions or recommendations to the RAP submission to the IJC.
- The WQB also will report on the RAP submission at the subsequent IJC semi-annual meeting.
- If the IJC does not respond to RAP submissions in an expeditious manner, the WQB will periodically remind the IJC, via written or verbal communication, of its obligation to respond, as a means of enhancing confidence that the IJC considers such public submissions in an appropriate manner.
- After the IJC has responded to a given RAP submission, the WQB will communicate with the RAP group regarding any follow-up actions to be undertaken by the WQB.

1.6 ADVICE FROM THE WQB TO THE IJC ON THE GOVERNMENTS' REPORTING RESPONSIBILITIES UNDER THE AGREEMENT

1.6.1 Introduction

Annex 2 of the Agreement outlines the procedures for reporting RAP and LaMP progress. Past experience suggests these procedures are inadequate, resulting in general dissatisfaction with the process. Accordingly, the IJC is considering how to best facilitate the reporting process, given the changing dynamics of the governments and jurisdictions. To assist in this effort, the IJC requested the advice of its Great Lakes Boards and Council regarding several discrete aspects and procedures under the Agreement.

1.6.2 IJC Request for Advice

The IJC's request for advice was presented to the WQB in the form of four questions, focusing on LaMPs, RAPs and status assessments, State of the Lakes Ecosystem Conference (SOLEC), and the IJC Biennial Forum. Most WQB members submitting responses tended to address the issues primarily from their jurisdictional roles. The IJC's questions and the WQB's consensus responses are as follows.

1. The new LaMP reporting approach is now producing considerable volumes of information, to be updated every two years. As required by the Agreement, the Commission has been commenting on the reports submitted by the Parties at the various stages after they were issued. Should the Commission comment on the LaMP 2000 reports and, if so, what process should the Commission use to develop comments and what should be the focus of those comments?

The general consensus of WQB members was that the LaMP process was a major undertaking involving massive amounts of information and data. At the same time, however, most of the information in LaMP updates has already been vetted through their respective public processes.

Although several WQB members recommended that the IJC continue to comment on the LaMP 2000 reports, ideally in face-to-face meetings between IJC staff and LaMP managers, the general consensus is that the IJC need not review all LaMP documents at all development stages. Rather, it should focus on specific LaMP components, namely: 1. strategic goals; 2. milestones; 3. progress in reaching milestones; 4. broader, region-wide issues; 5. issues not resolved within respective public consultation; or 6. when specifically requested by the governments. Any IJC conclusions or comments on these components could be transmitted within its biennial reports to the governments.

The RAP reports are no longer following the reporting format outlined in the Agreement, and even when they do, they are arriving at the Commission after a delay of one or more years.

Other individual suggestions were that review of work under the Agreement be done in a cooperative and supportive manner, noting that it would be counterproductive to discredit the work previously done by the governments. Further, the topic of human health was an area where most LaMPs and RAPs disagreed with the IJC, with the suggestion that one report on human health be prepared for the entire basin, rather than lake by lake. Several WQB members also commented on possible board activities in direct support of this task, suggesting that special attention be directed to ensuring that board members provide independent advice to the IJC. This was deemed necessary because many WQB members have direct involvement in the governments' programs and, therefore, might otherwise be seen as simply conveying the views of the governments.

2a. The RAP reports are no longer following the reporting format outlined in the Agreement, and even when they do, they are arriving at the Commission after a delay of one or more years. This tends to weaken the effectiveness of the Commission's comments. What role would be appropriate for the Commission to play in this new process?

WQB members submitted a range of responses. One observation was that the RAPs were needed to hold the governments to their obligations under the Agreement and should be a major IJC priority, including visits to AOCs proclaiming attainment of delisting targets and restoration of beneficial uses. The general WQB consensus, however, was dissatisfaction with the staged RAP reporting process currently outlined in the Agreement. Several WQB members

identified the Toronto RAP as a particular source of recent dissatisfaction, noting that the IJC neither acknowledged receipt of the recommendations from its public meeting nor took any steps to address the recommendations. It also was suggested that, although the Agreement clearly outlined the RAP reporting process, the governments were consistently not meeting the requirements. Thus, the rationale and/or relevancy for submitting any RAP reports and/or recommendations to the IJC were questioned.

It was further suggested that the issue of reporting, or lack thereof, was perhaps symptomatic of a bigger issue. To this end, the IJC comments should be more than technical in nature, should work to influence actions toward achieving RAP goals in a real way, and not be interpreted in isolation of the more general role described in the Agreement as a whole. In regard to improving the RAP reporting process, the IJC needed to elevate its stature and influence.

Additional specific suggestions were that the IJC should focus its attention on criteria for removal of designation of AOCs; 2. ensuring that RAP requirements of the Agreement are being met in a timely manner for specific AOCs; 3. partnerships and cooperation with RAP committees, including timely exchange of information; and 4. using the RAP reporting process to provide up-to-date 'snapshots' of the governments' progress in regard to RAPs.

2b. The Commission has also undertaken some status assessments and will be doing two more this year. How can the status assessments be more effective in moving the RAP process forward? Are there any other ideas as to how we can move the RAP process continually forward?

The responses of WQB members to this question were mixed. Several questioned the value-added role of the status assessments, suggesting the IJC, governments and the public would be better served with focused attention on RAP development and/or AOCs. Another perspective, however, was that the status assessments provided an opportunity for RAP practitioners to benefit from a thorough review of the process prior to any submissions to the IJC.

Several suggestions for improving the status assessments were offered, including: 1. approaching them in a cooperative manner and allowing the governments and respective states and provinces active roles in them; 2. consistency in how they are conducted among the AOCs; 3. clear objectives, guiding principles and/or vision; 4. candor from the IJC in regard to what it would like to do vis-à-vis the status assessments; and 5. ensuring draft assessments are not publicly released prior to their review by the governments.

3. SOLEC has made considerable progress on indicators and a significant volume of information was provided in Hamilton. How can the Commission build on this good work? What role, if any, is appropriate for the Commission in follow-up to SOLEC 2000 and the overall topic of indicators?

The WQB generally expressed widespread support for the SOLEC efforts. Several suggestions were offered on how the IJC could contribute to improving the process, including: 1. ensuring that the governments' indicator development also satisfies the IJC's needs; 2. encouraging the governments to provide support for SOLEC activities; 3. ensuring that the developed indicators accurately reflect the Great Lakes system and are helpful to local AOCs; 4. focusing on technical aspects of Great Lakes management efforts and staying away from reporting on RAP or LaMP status or trends; and 5. promoting the binational perspective and cooperation for Great Lakes indicators. It was also suggested that the IJC consider convening its own forum for discussing indicators and coming to its own conclusions about the SOLEC work.

4. The IJC's Biennial Forum in Montréal, September 2001, is an opportunity for the Agreement community to come together to share information and discuss issues. In what way can the changing dynamics of the Agreement described above be reflected in the workshops or discussions at the Forum?

WQB members offered a number of suggestions for improving both the forum content and process. Virtually all agreed on the positive value of this forum for discussing important Great Lakes issues, particularly for engaging the public and the governments in meaningful dialogue on the effectiveness of the Agreement.

Specific suggestions for improving the forum process included: 1. seeking the views of the governments and the public regarding their satisfaction of the RAP and LaMP reporting process; 2. having the IJC outline its own approach for delisting AOCs; 3. the need for thoughtful, staged debates on relevant Great Lakes issues, including inputs from the IJC Great Lakes boards and the Council of Great Lakes Research Managers; 4. progress reports by the governments and IJC accomplishments on its priorities; 5. options for near-term SOLEC themes and reporting options; and 6. encouraging stronger industrial participation at the forum.

1.7 CRITERIA FOR REMOVAL OF THE AOC DESIGNATION

1.7.1 Introduction

In its role as principal advisor to the IJC on water quality issues in the boundary waters of the Great Lakes system, the WQB reviewed the process for removing the designation of AOC as outlined in the Agreement. Annex 2, Paragraph 4(c) reads as follows.

The Parties shall cooperate with State and Provincial Governments to classify Areas of Concern by their stage of restoration progressing from the definition of the problems and causes, through the selection of remedial measures, to the implementation of remedial programs, the monitoring of recovery, and, when identified beneficial uses are no longer impaired and the area restored, the removal of its designation as an Area of Concern.

1.7.2 Current Perspectives of the Governments Regarding 'Delisting' AOCs

The WQB has devoted considerable attention to the criteria for removing the AOC designation for the 42 AOCs in the basin. Questions of interpretation of so-called 'delisting criteria' in Annex 2 generally focused on whether or not completion of implementation of remedial actions was sufficient to remove the designation of AOC for a given site, even if additional time is required before beneficial water uses are actually restored. This question was raised because the restoration of beneficial water uses for many AOCs might require additional time, even after completion of RAP implementation.

Annex 2 indicates that the governments shall classify AOCs by their stage of restoration, including removal of its designation as an AOC when identified beneficial uses are no longer impaired and the area is restored. Annex 2 also states that the IJC is to review and comment on the Stage 3 reports, but not to approve or disapprove the removal of the designation of AOC, which remains the prerogative of the governments. Nevertheless, there remain clear jurisdictional differences in interpreting removal of the AOC designation. Canada is proceeding with the designation of 'Areas of Recovery' for those locations in which RAP implementation is completed but for which restoration of beneficial water uses will require an additional period of time to achieve. Some U.S. states also have advocated removal of the AOC designation under these conditions. The goal is to reward incremental progress in restoring beneficial water uses, in contrast to an all-or-nothing approach that does not recognize actions already undertaken to restore an area.

. . . there remain clear jurisdictional differences in interpreting removal of the AOC designation. Canada is proceeding with the designation of 'Areas of Recovery' for those locations in which RAP implementation is completed but for which restoration of beneficial water uses will require an additional period of time to achieve. Some U.S. states also have advocated removal of the AOC designation under these conditions.

The U.S. Policy Committee is developing the U.S. position on this issue, including working with the U.S. states and the Environmental Protection Agency to delineate an acceptable process for evaluating and/or removing the AOC designation in the U.S. portion of the Great Lakes basin. A major goal is to develop a five-year strategy for the AOCs, including consistency regarding achievement of the restoration of beneficial water uses.

1.7.3 WQB Perspective on Designation of Restoration of Beneficial Water Uses

In recognition of the IJC's conclusion that the issue of 'delisting' AOCs will be a major problem for the governments, and that reconciliation of differences between the two countries will be difficult, the WQB elected to take a watching brief stance. The WQB acknowledges the differing governmental opinions, with a major concern being how to decide when beneficial water uses have been restored for a given AOC, including the role of natural recovery in this process. A related issue is whether or not removal of AOC

designation should be within the purview of individual jurisdictions, or strictly consistent with the language and requirements of the Agreement. The WQB believes a consistent approach to this issue is very important, including agreement by the Parties regarding consistency on the criteria for the designation of restoration of beneficial water uses. To this end, many Canadian RAPs will finish their remediation within the next few years, and an overriding issue will be whether or not their AOC designation should be removed upon completion of the remediation work.

Some public participants and ENGOs previously suggested that removing the AOC designation upon completion of its RAP, even though achievement of the RAP goals and the restoration of beneficial water uses will take additional time to achieve, provides the governments with a means of essentially washing their hands of this difficult issue. This perception undermines the abilities of the governments and the IJC to effectively address this issue.

1.7.4 Potential Roles for the WQB

The IJC has previously sought advice from the WQB in regard to measuring progress under the RAPs and LaMPs in a manner involving more than merely receiving the relevant reports. It has also sought advice regarding how to acknowledge incremental success in achieving the RAP goals, as a means of facilitating RAP implementation throughout the Great Lakes basin. Accordingly, the WQB is considering alternative roles for itself in addressing this issue, as follows:

- continuing to convene annual public meetings in AOCs to engage the WQB and the IJC in discussions on local issues, as well as in celebrating local incremental successes;
- monitoring the progress of the governments in developing and/or modifying policies, procedures and guidelines for removal of the AOC designation, including providing advice to the IJC on the acceptability of the policies, procedures and guidelines;
- advising the IJC on a consistent interpretation of Annex 2 regarding the removal of AOC designation; and/or
- hosting workshops or other appropriate meetings to facilitate discussions among AOC community members and the governments and jurisdictions regarding a consistent viewpoint on removal of the AOC designation, and for developing appropriate recommendations for the IJC on this issue for the Great Lakes basin.

Within the possibilities inherent in these potential roles, it is the continuing goal of the WQB to develop advice to the IJC on the most appropriate and environmentally-defensible means of removing the AOC designation, and the restoration of beneficial water uses, for those situations where this action is justified.

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1999-2001
Priorities Report
Chapter 2

The Great Lakes Science Advisory Board

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DISCLAIMER

Every attempt has been made to attribute the expert opinions and comments in this report and to clearly distinguish them from the advice of the Science Advisory Board to the International Joint Commission. While these views are important and relevant for the report, they do not necessarily represent the views of the board or the International Joint Commission.

2.1 INTRODUCTION

Under the Great Lakes Water Quality Agreement, the Science Advisory Board (SAB) was established to provide scientific advice to the International Joint Commission (IJC) and the Great Lakes Water Quality Board (WQB) and is responsible for developing recommendations on all matters related to research and the development of scientific knowledge pertinent to Great Lakes water quality. Such a broad mandate requires a multi-disciplinary approach and accordingly, members are appointed from each country by the IJC with expertise in the natural, physical and social sciences. Within the broad mandate of the board, there are several processes that determine what is to be done and which of the myriad problems or scientific issues are most salient in terms of water quality, and for consensus building to support SAB recommendations.

Major activities of the SAB are largely tied to the IJC's biennial cycle. Development of board priorities by the IJC is based on consultation with its boards at the beginning of each biennial cycle and with the public during the biennial Public Forum. The Commission assigns a lead role to each of the advisory groups, according to whether the question is one of policy, science or research. A sole priority topic was initially assigned to the SAB for the 1999-2001 biennial cycle titled *Methodology for Assessing Community Health in Areas of Concern*, building on the previous work of the board in human and community health (1992 workshop in Ann Arbor, Michigan titled *Our Community, Our Health*, IJC 1994). Throughout the past decade, as a result of significant investments by the United States and Canadian governments in Great Lakes environmental health research, there has been a new appreciation of the injury to human health from exposures to persistent toxic substances, particularly from the consumption of Great Lakes fish. Of particular concern are the irreversible changes in fetal developmental processes as a result of maternal consumption of Great Lakes fish prior to and during pregnancy. The challenge for researchers, managers and policy makers is to determine the relevance of the effects identified by the scientific studies and the extent of injury occurring in critical subpopulations in communities, particularly in Areas of Concern (AOCs).

During the preparation of its Tenth Biennial Report on Great Lakes Water Quality, and in assessing the threat to human health from persistent toxic substances during its review of Annex 12, the IJC noted its serious concerns about this injury to human health from exposures to contaminants in Great Lakes fish. Generally, the policy response of governments is to issue fish consumption advisories. As stated in the report, this can only be considered an interim solution pending restoration of the chemical integrity of the ecosystem. Further, Commissioners requested additional advice on the adequacy of the advisories during the 1999-2001 biennial cycle and thus an additional human health related assignment was referred to the board.

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A third major activity of the SAB, the review of Annex 1 of the Great Lakes Water Quality Agreement, evolved from the preliminary assessment of Lake Michigan Mass Balance data, by the SAB's Work Group on Parties Implementation. The original intent of this activity, to compare Lake Michigan Mass Balance data with Annex 1 Specific Objectives, led the work group to address broader issues related to the current relevance of Annex 1 to the Agreement, and its usefulness as a framework for reporting the status of Great Lakes water quality. The Commission accepted the advice of the board to fund further study, and in September 2000, this initiative began.

Several other important scientific issues were identified by the board and addressed with the assistance of student teams from Clemson University on the review of the State of the Lakes Ecosystem Conference (*SOLEC*), and from the University of Guelph of the review of *Nonpoint Sources of Pollution from Land-use Activities*.

The SAB also collaborated with the International Air Quality Advisory Board (IAQAB) on *Atmospheric Deposition Modeling to Develop Control Strategies*; with the Water Quality Board on the *Review of the Great Lakes Binational Toxics Strategy*; and with the Council of Great Lakes Research Managers on the *Application of a Methodological Framework and a Proposed Process for Agreement Institutions in Addressing Emerging Issues in Great Lakes.*

The board completed a thorough review of its own internal processes for fulfilling its role under the Agreement, and developed *Procedural Guidelines* encompassing its administrative processes and work planning, the conduct of board workshops and the preparation of the Biennial Report on the Priorities and Progress under the Great Lakes Water Quality Agreement.

During this biennial reporting cycle, the SAB held two public meetings: at the IJC Biennial Meeting in Milwaukee, Wisconsin, held September 1999 (#115) and during the IJC status assessment of the Niagara River AOC, held in Niagara Falls in November 2000 (#120). Both meetings reflect the ongoing practice of the board to encourage public involvement and interaction with the board.

Given the ease of electronic communication with the Internet, there are greater opportunities than ever for interested citizens to be aware of their Great Lakes science heritage and to benefit from its discoveries in terms of societal change. Scientific knowledge, however exciting, is necessary but not sufficient as a sole basis for actions, as it must be applied wisely by decision makers, and their actions must receive public support, in order for progress under the Agreement to be sustained. Great Lakes citizens are encouraged to follow the board activities and advice by visiting their web site at the IJC home page at http://www.ijc.org/boards/sab/index.html or to contact the board secretary Mr. Peter Boyer at boyerp@ijc.windsor.org for further information.

Finally, the board would like to acknowledge the efforts of all of the non-board contributors to the report, many of whom participated as invited experts at board meetings, industry tours, workshops and work group meetings. They include: Annette Ashizawa, Seth Ausubel, Thomas Baldini, Thomas Barnard, Michael Basile, Judy Beck, Mary Lynn Becker, Matthew Becker, Ryan Bodanyi, Ken Bondy, Barry Boyer, Jim Brophy, Jean Burton, Tanya Cabala, Michael Campana, Richard Carrier, Alice Chamberlin, Mathew Child, Theo Colborn, George Costaris, James Cowden, Joseph DePinto, Krista Devine, Jim Drummond, Abdel El-Shaarawi, Rose Ellison, Thomas Emery, Rick Esterline, John Eyles, Sharon Fedman, Ralph Ferguson, Joel Fisher, Irene Gauthier, Matt Hare, Lucy Harrison, Jim Hartnett, Maureen Healey, John Heatley, Allen Heimann, Henry Henderson, Adam Hess, Paul Horvatin, Robert Huggett, Irene Ilia, John Jackson, Lin Kaatz Chary, Neil Kagan, Rimas Kalinauskas, Wilfried Karmaus, Margaret Keith, Elaine Kennedy, Daniel King, David Kohoko, Horace Krever, George Kuper, Wendy Larson, Kathleen Law, Mike Lawson, Michael Leffler, Matthew Longnecker, Kim Lund, Kevin Lynch, Yang Mao, John Marsden, Barbara McElgunn, Errol Meddinger, Russell Moll, Penelope Moskus, Tom Muir, Michael Murray, William Muszynski, Susan Nameth, Melanie Neilson, Scott Painter, Dale Phenicie, Christian Pupp, Lisa Richman, Kristina Riggle, Amy Roe, Rick Sherrard, Ted Schettler, Gary Silverman, Saulius Simoliunas, George Spira, Doug Spry, Helen Tryphonas, Michael Twiss, Raymond Vaughan, Marcia Valiante, John Vena, Anita Walker, Reuben Warren, Bernard Weiss, Brenda Wheat, Jim Whitaker, Marj Williams, Don Williams, Autumn Workman, Michael Zegarec and Donald Zelazny.

2.2 HEALTH

2.2.1 Methodologies for Community Health Assessment: Measuring Injury to Health

Scientific, Diplomatic and Political Responses to Great Lakes Pollution

For more than 90 years, the International Joint Commission has been assisting the United States and Canadian governments in preventing and resolving potential disputes concerning the use of the boundary waters between the two countries, from coast to coast, under the Boundary Waters Treaty of 1909. Because the International Joint Commission is a diplomatic organization that undertakes its work by examining issues that are under dispute, it is not only a political, but also a scientific organization. Many of its responsibilities concern water use, diversions, allocations and other aspects of water quantity. But in the past 40 years, there has been a growing emphasis on water quality, particularly through the studies leading up to and subsequent to the signing of the 1972 Great Lakes Water Quality Agreement by the United States and Canada. The Agreement itself was both a political and scientific response to the widespread reports of deteriorating water quality in the Great Lakes basin.

At the core of the water quality aspects of the Boundary Waters Treaty is an agreement that the two governments would not pollute the boundary waters to the injury of health or property on the other side. However, in the preamble to the Great Lakes Water Quality Agreement there is an acknowledgment by the governments that this has happened and that the boundary waters in the Great Lakes basin have been polluted to the injury of health and property on the other side.

Initial priorities and programs were oriented to documenting and controlling eutrophication and developing and implementing common water quality objectives. But in the 1960s and through the 1970s, Great Lakes scientists began reporting observations of gross effects of persistent toxic substances on the reproduction and development of avian wildlife and ranch mink. These observations influenced the renegotiation of the 1978 Agreement. In the 29 years since the signing of the original Agreement, there have been enormous advances in documenting this injury to many species and taxa of wildlife and in formally demonstrating the causal links to specific pollutants. It has, however, proven more elusive to document the injury to human health from exposures to pollutants. Initial cohorts were established in the 1970s to investigate exposures from consumption of Great Lakes fish and the first cohort to examine possible effects on infant development from maternal consumption of Great Lakes fish contaminated with persistent toxic substances (Fein et al. 1983) was established in 1980. By the end of the 1980s, there was such a remarkable concordance between the developmental effects that had been observed in wildlife and those seen in studies of infants that it lead to the successful formulation of the unifying hypothesis of endocrine disruptors as a mechanistic explanatory principle linking effects on reproductive, developmental, neurological, endocrine and immune processes (Colborn and Clement, 1992).

These scientific findings were politically influential in both countries. In the late 1980s, Health Canada instituted its Great Lakes Health Effects Program, and in the early 1990s, the United States, through the amendments to the Clean Water Act, mandated the Agency for Toxic Substances and Disease Registry (ATSDR) to fund epidemiological research through the Critical Programs Act. The ATSDR studies confirmed that fish consumption is the major pathway of exposure to persistent toxic substances, such as dioxin, polychlorinated biphenyls and mercury, and identified at-risk populations, including Native Americans and other minorities, sport anglers, the elderly, males and females of reproductive age, and fetuses and infants of mothers consuming contaminated Great Lakes fish (Johnson et al. 1999). In human studies, increasing levels of sport fish consumption have been associated with difficulties in conception for Michigan sport fish anglers (Courval 1999). ATSDR has funded research and other community-based studies have the ability to influence policy and public health practice, thereby directly enhancing the health status of vulnerable communities through identifying at risk groups consuming Great Lakes sport fish and by disseminating outreach materials alerting the public about safe fish consumption.

Community Health and Areas of Concern

In the mid-1980s, the IJC expressed concern about the recurrent reports from the governments of locations around the Great Lakes where water quality was out of compliance with water quality objectives, and particularly in relation to pollution by persistent toxic substances. These locations

became known as Areas of Concern (AOC) and were intended for special programs to restore water quality through the development and implementation of Remedial Action Plans.

Health Canada, through its Great Lakes Health Effects Program, undertook a research project to investigate whether the incidence rates of diseases were different in the 17 Canadian AOCs compared with the rest of Ontario and to generate hypotheses about whether these differences might be related to exposures from local sources of pollutants. The data and statistics in the reports were compiled from a national databases kept by Statistics Canada for selected health endpoints that might be related to pollution and included mortality, morbidity as hospitalization, congenital anomalies and birth weights. There was considerable nervousness within Health Canada about releasing the 17 reports after comments were received from the local medical officers of health and from officials in Environment Canada and in the Ontario Ministry of Environment. But in November 1999, the reports were released to the public, just before the Great Lakes Health Effects Program was terminated on March 31, 2000.

Partly as a result of the availability of the Health Canada reports, the International Joint Commission directed the SAB to examine methodologies for assessing whether human health effects of pollution are occurring in communities in the Great Lakes basin. The SAB's Work Group on Ecosystem Health developed a workplan for a *Workshop on Methodologies for Community Health Assessment for Areas of Concern*, which was held on October 4 and 5, 2000 in Windsor, Ontario. The primary concerns to the members of the work group were reliable interpretations of the health data and statistics for the Health Canada reports, and the apparent absence of any comparable data for the AOCs in the United States.

The Workplan

- Review the 17 Great Lakes Health Effects reports to prepare a synthesis of the health status within the communities in the Canadian AOCs, with particular regard to the health status in Windsor.
- Examine the processes being employed in these communities to respond to this new information, with a focus on the response in Windsor.
- Inquire whether comparable U.S. data can be obtained.
- Examine how to obtain data on more subtle quality-of-life indicators within the AOC communities, including such health endpoints as thyroid dysfunction, diabetes and immune dysfunction.
- Obtain indirect evidence from monitoring the incidence of endocrine effects on wildlife populations that are geographically distributed close to AOCs.
- Investigate the possible links between the incidence of disease and exposures to pollutants.
- Investigate the associated societal costs.

Several past activities had been undertaken by the IJC and the governments to gain understanding of the Great Lakes health issues at the community level. In 1992, the Work Group on Ecosystem Health held a workshop titled *Our Community, Our Health: Dialogue Between Science and Community*. In 1995, Health Canada published two documents titled *Investigating Human Community Exposure to Contaminants in the Environment* and *A Community Handbook*. In 1999, the Great Lakes Science Advisory Board held a *Meeting to Assess Scientific Issues in Relation to the Effects of Persistent Toxic Substances in Relation to Lakewide Management Plans*, and identified the need to assemble epidemiological evidence related to the effects on human communities. Much of the work undertaken has traditionally related to the incidence of cancer. With the recent publication of several papers documenting the experimental induction of a variety of effects from prenatal exposures to low doses of endocrine disruptors, there is now a priority need for communities to investigate whether these subtle effects are occurring among individuals within their communities.

Community health and injury to health from exposures to pollutants connote environmental epidemiology. Epidemiology has been undergoing a period of intellectual crisis and reassessment (Susser and Susser, 1996a, b; Pearce 1996). The crisis has been precipitated by the limits of the methodology for detecting significant relationships between the incidences of disease and exposures to putative risk factors. The reassessment has been prompted by a recognition of the need to reconnect the science of epidemiology with the practice of public health in its ongoing attempts to intervene effectively with large scale increases in the incidences of certain diseases of uncertain etiology. In the quest for making definitive causal statements relating disease incidences to specific factors, to determine whether preventive interventions are feasible, there has been a recognition of the need to develop an *eco-epidemiological* approach by integrating molecular epidemiology, with its orientation toward mechanistic hypotheses, with individual and population epidemiology, and to cast these in a social, economic and political context (Susser and Susser, 1996b). There are particular challenges of applying this new approach to environmental epidemiology, with all the attendant difficulties of measuring, estimating or inferring exposures (Pekkanen and Pearce, 2001). The International Joint Commission, comprised of the dual attributes of politics and science, first applied an *eco-epidemiological* methodology to several Great Lakes case histories in 1989, at its first *Cause-Effect Linkages Workshop* (Fox 1991).

Within the Great Lakes basin, the political context of the implementation of the Great Lakes Water Quality Agreement has not changed significantly since the early 1980s when the shift to the political right resulted in a general withdrawal of environmental issues from the political agenda of both

countries. The consilience of results of so many epidemiological studies, together with the extensive surveys of the concentrations of persistent toxic substances in the Great Lakes environment, and the research on the mechanistic processes, has created a strong dynamic tension with the maintenance of these existing policies formulated more than 20 years ago. The workshop was structured to explore this consilience and lay out the diversity of evidence and implications of not implementing the restoration provisions of the Agreement. The papers from the *Workshop on Methodologies for Community Health Assessment for Areas of Concern* are being prepared for publication in the journal of the National Institute of Environmental Health Sciences, *Environmental Health Perspectives.*

One of the critical health endpoints from exposures of communities to toxic substances concerns the effects on neurological development. In his keynote address at the *Workshop on Methodologies for Community Health Assessment for Areas of Concern*, Ted Schettler, (Schettler et al. 1999) of the Greater Boston Physicians for Social Responsibility, elaborated the evidence of the unique vulnerability of the developing brain to environmental agents, such as organochlorine compounds and metals, at exposure levels that have no lasting effect in the adult. This has been known for a long time, since there are even biblical prohibitions against drinking alcohol because of the long-lasting damage to brain development and function caused by prenatal alcohol exposure. Where registries have been established, the collection of health information on behavioural, learning and developmental effects has been significantly enhanced.

Recommendation

The SAB recommends the following to the IJC.

- **Recommend that the Parties establish prospective and retrospective registries of neurological deficits to identify subpopulations at risk from exposures to developmental toxicants.**

Health Effects in Canadian Areas of Concern: 17 Health Canada Reports

The 17 Health Canada reports on health data and statistics for diseases and conditions that might be related to pollution in the communities in the Canadian AOCs, represent an enormous database that potentially could contribute to the formulation of statements that could provide a rational basis for remedial action plans to restore environmental quality under the Great Lakes Water Quality Agreement and under the Canada - United States Air Quality Agreement. The reports with the data and statistics can be found at http://www.hc-sc.gc.ca/ehp/ehd/bch/bioregional/healthdata.htm.

The 17 Health Canada reports on health data and statistics for diseases and conditions that might be related to pollution in the communities in the Canadian AOCs, represent an enormous database that potentially could contribute to the formulation of statements that could provide a rational basis for remedial action plans to restore environmental quality . . .

Before the reports can be utilized for this or any other purpose, such as selecting community health indicators, they needed to be interpreted. The objective of the IJC *Workshop on Methodologies for Community Health Assessment for Areas of Concern* was to focus on methodologies. The secondary objective was to provide detailed descriptions of the community health status within AOCs. The following is a brief review of the methodology that Health Canada used to compile the reports and of the methodologies used to interpret the database. Health Canada detailed the methods used in the study under the following headings: Assigning Standard Geographic Codes; Selecting Health Outcomes; and Gathering and Analyzing the Data.

Assigning Standard Geographic Codes

Each of the 17 AOCs was described using Standard Geographic Codes that contain provincial, Census Division and Census Sub-Division information, and that coincide with the Canadian process for collection of human health data. Each of the 17 reports contained detailed background information on: the study area and its population; methods used in the study for assigning Standard Geographic Codes; and gathering associated health data. The population within each area in 1991 was determined and compared, as a percentage, with the Ontario provincial population, which was 10,104,317. Data for the incidence rates for diseases and disorders for the populations in all the AOCs were age standardized by gender and comparisons made with the incidence rates for the rest of Ontario.

Selecting Health Outcomes

Health Canada selected approximately 70 categories of health endpoints, using the International Classification of Diseases (ICD 1992). Because this project was undertaken by the former Great Lakes Health Effects Program under the mandate of the Great Lakes Water Quality Agreement, there was an orientation toward selecting diseases and disorders on the basis that they might plausibly be linked to exposures to

contaminants in the Great Lakes environment based on references in the published literature. Appendix I. contains the selected health outcomes based on the Ninth Edition of the International Classification of Disease (1992).

Gathering and Analyzing the Data

Population census data for the years 1986 and 1991 were accessed from the Demography Division of Statistics Canada to calculate mortality and morbidity rates on an age-specific and gender-specific basis. Mortality data were provided to Health Canada's Center for Disease Control by Statistics Canada and included information on the cause of death, reported by ICD code, the last location of residence based on the Census Sub-Division, and the sex and age of the deceased. Hospital separations data were supplied by the Canadian Institutes for Health Information, and included data on sex, age and residence, and the ICD code for the diagnosis for the main cause of hospitalization. Health Canada warned about some of the pitfalls of using hospital separations data and these concerns included multiple visits or transfers between or within hospitals. They also exclude visits to clinics, doctor's offices and outpatient departments. Similarly, there may have been difficulties in transforming residence information, based on a postal code or an Ontario Residence Code, into a Census Sub-Division. Further, these data for Ontario do not include Ontario residents who were hospitalized in another province.

These pitfalls were addressed in the Health Canada reports in analyzing the data and statistics. For example, in using the hospital separations data, Health Canada referred to morbidity rates rather than incidence rates. The data were initially analyzed using 19 age groups, but for simplification of reporting were combined into five age categories: all ages; 0-24 years; 25-44 years; 45-74 years; and more than 75 years. The age adjusted mortality and morbidity rates were compared with the rates for the rest of Ontario and ratios calculated comparing the local rates with the provincial rates. In the 17 reports, Health Canada included numerous references to aid in the interpretation of the data and statistics. In addition, several of the reports of the former Great Lakes Health Effects Program of Health Canada (1995, 1997, 1998) proved invaluable in the interpretation of the 17 reports on the health data and statistics particularly in relation to possible causal factors, including occupational exposures to chemicals and lifestyle factors such as alcohol and smoking.

The interpretation of the reports has proved to be a challenge, even for those with advanced degrees in public health. The challenges can be divided into: those associated with the diversity of health outcomes selected; useful ways of aggregating the endpoints into categories; and interpretation of the tables into comprehensible displays and narratives. In the interpretation of the reports, the following three approaches have been taken by the Work Group on Ecosystem Health and its contractors:

a. **mapping** of the distribution of the statistical significance of the ratio of the incidence rate for a particular health endpoint compared with the rate in the rest of Ontario;
b. **extended narrative** of the elevated incidences of diseases or conditions within a population in a specific Area of Concern and comparisons with other locations with similar population size and racial profile; and
c. **statistical analyses** to rank Areas of Concern on the basis of the aggregated severity of incidences of diseases and conditions and to select indices of environmental health.

Mapping

Based on the Health Canada data and statistics, Dr. John Eyles of McMaster University prepared maps of the distribution of incidence rates for some of the diseases and conditions compared with the rest of the Ontario. He concluded that the Health Canada findings present a complex picture of health outcomes in the Canadian AOCs. In some respects, he felt, such a complex picture presents a scientific maze for policy makers in the IJC and in the federal and provincial bodies. There is so much that is potentially significant that it may be difficult to know where to concentrate finite and limited resources. While mapping the Health Canada statistical data provides a useful and user-friendly lens on the issues, there do remain methodological issues connected with the critical data and well documented as a series of caveats in the Health Canada reports themselves. Further, while the rates are usually standardized to the provincial population, this may not be the best comparator for a binational body like the IJC. It is of central importance to Ontario-based policy makers in public health and environmental regulation. And while the identification of statistical significance is important, such an approach may indicate issues of low incidence or even low public health relevance, given current knowledge and priorities.

Dr. Eyles compared the standardized rates, for the selected health outcomes for the various AOCs, with the rates for the rest of the Ontario. Those outcomes in which the ratios of the standardized rates were statistically significantly above one, were identified, based on the argument that any *above average* deviation from the province is worthy of note. This technique identified, for example, the Detroit River Area of Concern for both men and women, and the Niagara River (women only) as worthy of further investigation, even at the ecological level. Thus, it may be worth doing some analysis of census data to see the associations between some health determinants and the identified health outcomes. In this way, it will be possible to account for, at the ecological level, some of the non-environmental determinants of health. Further

work will enable a discussion of potential explanations of the associations between different health outcomes and environmental factors operating in the Canadian AOCs.

Extended Narrative: Focus on Windsor, Ontario

Marcia Valiante of the University of Windsor set the historic context of the bilateral concerns about transboundary air pollution at the Detroit River. Windsor and the outlying areas have had poor air quality as a palpable fact of life for the last 100 years. This region is also subject to greater incidences of certain health problems than other areas in Ontario. Investigating the link between these two facts is like assembling a jigsaw puzzle with many pieces missing and no picture to guide the task of assembling the available information about the state of the air in this region and comment on the relationship between local and transboundary sources.

Marcia Valiante noted that Windsor is uniquely located. It is a city of 200,000 residents (with another 100,000 in neighboring communities in Essex County), yet it has air quality that is generally worse than that of the largest cities in Canada. This is in large part because Windsor's air quality is closely linked to emissions from industry and transportation sources in Detroit and the rest of southeast Michigan, in the larger upwind context of the Great Lakes basin. But Windsor is not simply a faultless victim of another jurisdiction's neglect; local industry and transportation sources also contribute harmful emissions to the atmosphere.

She pointed out that air pollution is usually regulated on the basis of its health impacts due to direct inhalation. Standards in both the U.S. and Canada reflect this traditional concern with air emissions. More recently, other concerns have emerged. Studies have shown that there is a proportionately significant contribution from atmospheric deposition to the Great Lakes for certain persistent substances, such as PCBs and mercury, which may then build up in the environment to harmful levels. As well, many substances no longer emitted locally are still detected in the air and water due to atmospheric transport from distant sources. Finally, the atmosphere allows for the transformation of some substances into other compounds that can then have effects far downwind. This is the case with acid rain and smog. While understanding all of these interrelationships is important to a complete picture of air pollution's impacts, it is difficult to get that complete picture due to major information gaps.

Of the 17 Canadian AOCs, Windsor, Ontario seems to be the municipality ranked among the highest for incidences of diseases that might be related to pollution. Jim Brophy of the Occupational Health Clinics for Ontario Workers and Michael Gilbertson of the International Joint Commission used the Health Canada health data and statistics for the Detroit River Area of Concern to provide an extended narrative of the incidence rates of mortality and of cancer, of morbidity as hospitalizations, and of congenital anomalies. Mortality and morbidity rates from all causes were higher than in the rest of the province. Anomalously high rates of diseases included: various cancers; endocrine, nutritional, metabolic and immunity disorders; and diseases of the blood and blood-forming organs; nervous system and sense organs; circulatory and respiratory systems; digestive system; genitourinary system; skin and subcutaneous tissue; musculoskeletal system and connective tissues; congenital anomalies and infant mortality. These incidence rates for most diseases were much higher than those in Hamilton, another industrial municipality in southern Ontario, suggesting that, in addition to a variety of local sources of industrial pollution from automobile manufacturing and use, there are transboundary sources of air and water pollution from Detroit that are potentially important causes of these health outcomes in the Windsor AOC. New United States and Canadian websites have been established that contain details of ongoing releases of toxic substances from industries and municipalities in Detroit and Windsor (http://www.scorecard.org and http://www.scorecard.org/pollutionwatch/, respectively).

This pilot project by Health Canada would seem to be a useful preliminary method of integrating human health concerns and of priority setting for the administration of the Great Lakes Water Quality Agreement and the Canada - United States Air Quality Agreement. For the detailed community health profile for Windsor and the comparison with Hamilton, Ontario, see Appendix I.

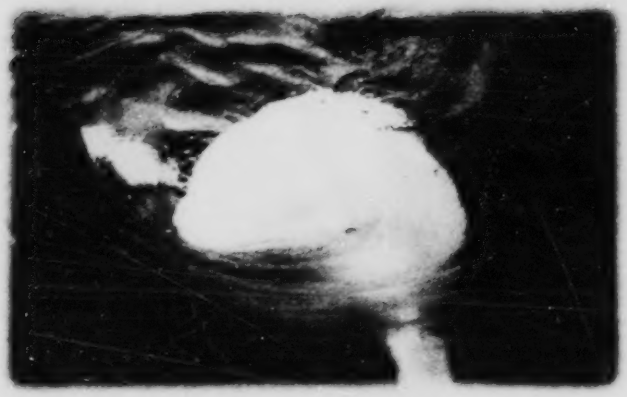
Further Statistical Analyses

The availability of electronic versions of the Health Canada data (http://www.hc-sc.gc.ca/ehp/ehd/bch/bioregional/healthdata.htm) and the provision of significant funding by Environment Canada for the development of indicators provides an opportunity to further analyze these databases. For example, ranking, cluster analysis, correlational and principal component techniques could provide better descriptions of the disease profiles in the most polluted areas and selection of particular diseases that might most reliably be used to indicate the environmental health status in a community exposed to pollutants.

Responses from the Medical Officers of Health

After Health Canada had prepared reports on the health data and statistics for each of the 17 Canadian AOCs to generate hypotheses about the possible role of pollution on the incidence of mortality, morbidity and congenital anomalies,

the respective report was sent to the local medical officers of health for information. The SAB then contracted with Dr. John Eyles to undertake a brief survey of the medical officers' responses to these reports. In every instance, the reports were referred to staff of the public health units, many of whom found the reports useful and who assisted in interpreting the reports.



There were, however, several concerns raised with Dr. Eyles about the reports. They were described as being too technical and dense and there were concerns expressed that, despite the following caveats, they might raise more questions than answers.

- They would have been more useful if the reports had contained an analysis and summary of the findings.
- Some of the populations in the AOCs were small and therefore provided limited statistical power for assessing the significance of the data.
- The use of hospitalization data may reflect the styles of practice at the facility rather than underlying health problems.
- The geographic boundaries of the AOC may not correspond to those of the public health unit and thus the reports were of limited value for their responsibilities.

The survey indicated that there may be a difference of opinion between the medical officers of health and the members of the public within a community about whether pollution is an important determinant of health. The diseases and risk factors that have been the traditional concerns of the medical officers of health include smoking, nutrition, heart disease, respiratory illness and cancer, and that environmental pollution tended not to be viewed as a factor affecting public health. The public, however, tends to view pollution as more important in determining diseases, especially in industrial settings, but this was viewed by some medical officers of health as a product of the media. Apart from cancer, respiratory disease, especially asthma, and the exacerbation of other disease conditions, such as heart disease and diabetes, the medical officers of health tended to be unclear about any connection between human health and pollution, while waiting for new evidence that could change their minds.

There were no plans on the part of the medical officers of health to release the reports to the general public in their Area of Concern. While most of the medical officers of health recognized that the statistical and epidemiological caveats had been addressed, they believed that the reports could amplify public concern over health problems in the AOCs, given the statistical significance of the presence of so many health end-points. They believed that the populations in their AOC fared no better or worse than the other Ontario and Canadian populations, that public trust in all government institutions, including public health, is fragile, and that the reports could, when there is no solution, frighten the public.

Recommendations

The SAB recommends the following to the IJC.

- **Recommend that the Parties establish institutional health structures at the local and regional level that can effectively investigate and respond to community health concerns that may be caused by chemical pollutants.**

- **Link human epidemiology to exposure data on air, water, sediments and biota in the preparation of future reports on Remedial Action Plans and Lakewide Management Plans.**

Availability of Health Data in the United States

The Work Group on Ecosystem Health let two contracts to assess the availability of comparable health data for the eight Great Lakes states. One contract was with a student of Dr. David Carpenter at the State University of New York at Albany who collected information on the availability of health data in New York state. The second contract was with a student of Dr. Diane Henshel of the School of Public Health and Policy in Indiana University at Bloomington. The goals for these studies were to assess the availability of health data in the eight Great Lakes states: Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania and Wisconsin. The specific aims were to:

1. identify the status of the development of health data-bases (i.e. health registries) and the collection practices in each state and in the municipalities designated as an Area of Concern;
2. identify the accessibility of the public health databases relevant to exposures to pollutants;

3. characterize the quality of each database; and
4. identify the barriers to database access and information on database quality.

In order to quantify data accessibility, the state databases were ranked on several parameters that affect the usefulness of the public health databases for research purposes. Overall, the New York public health databases and registries stand out among the eight states for completeness and accessibility to researchers. The Illinois and Wisconsin databases rank just below that of New York, followed by the databases for Michigan and Pennsylvania. What registries exist for public health databases in Indiana are difficult to access. Databases for the Great Lakes region of Ohio are not accessible, although the public health databases for the rest of the state are available. The Minnesota registries do not present information at an individual level, and are therefore of minimal use to researchers trying to correlate data across multiple endpoints. In sum, there is too little consistency in the collection and availability of public health information across the eight Great Lakes states, making it more difficult for researchers to compare and use public health data on a region-wide basis.

In order to quantify data accessibility, the state databases were ranked on several parameters that affect the usefulness of the public health databases for research purposes.

In New York state, the Statewide Planning and Research Cooperative System records diagnoses by International Classification of Disease (ICD) code for all patients admitted to state-regulated hospital facilities. There are six AOCs in New York, and three, the Buffalo River, Niagara River and 18 Mile Creek, are contiguous in western New York and have similar contaminants. These records can be utilized to compare the incidences of selected diseases reported in hospitalized patients who reside in zip codes that are within 15 miles of any of these sites to those of residents in the rest of New York state. Dr. Carpenter found significant elevations of disorders of the female genital tract, primarily due to endometriosis, and thyroid disease in women at all ages above 25 years, and significant elevations of diagnosis of ischemic heart disease and diseases of arteries, arterioles and capillaries in both men and women at some but not all age groups. The incidence of diabetes was significantly elevated in both men and women in the age range 25-44 years, but was significantly less in ages 55-74 years. Disease of the ovaries and testes were not different from the rest of New York. While many factors influence incidence of thyroid, genital and heart disease and diabetes, these results are consistent with the hypothesis that exposure to environmental contaminants through residence near polluted sites may be contributory.

There is a paradox between the need to access information on the health of individuals in order to operate a complex health care system with care that is accessible, efficient and of high quality and the need to protect the privacy of personal health care information. In Canada, there has been an impressive record of protecting the privacy of an individual's health information while making data available to ***bona fide*** health researchers. There are, however, bills both in the Federal Parliament of Canada and in the Ontario Provincial Legislature to introduce new legislation that may make access to and use of health data more complicated. Individual consent may be required to use information in new ways that had not been contemplated when the data was originally collected. Stronger requirements for obtaining these kinds of consent have been incorporated into legislation in the United States and in Europe.

Recommendations

In the preparation of evidence of injury to human health from exposures to pollutants at the boundary, in accordance with Article IV of the Boundary Waters Treaty, the SAB recommends the following to the IJC.

- **Recommend that the Parties facilitate the access of researchers to health information, while not compromising the rights of individuals to privacy and confidentiality.**

- **Recommend that the Parties make representations, with respect to pending legislation on the privacy and confidentiality of health information, to ensure that the capacity to monitor long term trends in pollutant-induced diseases and disorders is not jeopardized.**

Biochemical Epidemiology

Glen Fox of the Canadian Wildlife Service, working at the biochemical and individual epizootiological levels, cited studies of Great Lakes wildlife species afflicted with thyroid and other endocrine disorders, metabolic diseases, altered immune function, reproductive impairment, developmental toxicity, genotoxicity or cancer, attributable to exposures to persistent organic pollutants, particularly PCBs, PCDDs and PAHs. The frequency and severity of these effects occurred in the most contaminated sites of Green Bay, Saginaw Bay, Lake Ontario, the St. Lawrence estuary, and, more recently, Lake Erie, some of which are Areas of

Concern. Because these health impairments in wildlife resemble those observed with increased incidence in human subpopulations in one or more AOCs, wildlife could be used as a sentinel of the likely biochemical effects occurring in exposed human communities. These wildlife data were gathered as a result of academic research or research-based monitoring, rather than a formal effects monitoring program. While there are adequate long-term monitoring programs to document trends in concentrations of persistent toxic substances in the Great Lakes environment, there is no formal existing program for gathering long-term evidence for determining trends in the incidence and severity of their effects in wildlife. Such a program, using one or more sentinel wildlife species, would allow the Parties to the Great Lakes Water Quality Agreement to optimally use such information as a basis for decisions and policies regarding the effects of chemical exposures on human populations.

Recommendations

The SAB recommends the following to the IJC.

- **Recommend that the Parties develop a coordinated binational monitoring program to determine the incidence of health effects in wildlife that have been attributed to exposures to persistent toxic substances.**

Current human health and wildlife monitoring programs sometimes have levels of chemical analytical detection that are well above the concentrations at which biological effects occur.

- **Recommend that the Parties monitor the chemical exposures of human and wildlife populations using limits of detection appropriate to the known toxicology of these substances.**

Three papers explored the possibility of using the distribution of endocrine and immune diseases in human communities to identify small populations at high risk and indicate Areas of Concern. The requirements for diseases to serve this purpose include:

- agreement that the disease and markers can be employed as valid health indicators;
- the necessity that the disease have a short latency period in order to facilitate early detection;
- full clinical manifestation of the disease; and
- easy ascertainment from population-based investigations or from registries.

The first of these three papers was by Dr. Wilfried Karmaus concerning the use of thyroid disease. Although there is evidence that alterations in thyroid hormones are related to environmental exposures, thyroid disorders do not seem well suited to identify community exposures to thyroid active substances. While environmental exposures can produce

The rates of both type 1 and type 2 diabetes mellitus have been increasing in the U.S. and elsewhere, and genetic factors account for less than half of the new cases. These observations suggest that environmental factors cause both type 1 and type 2 diabetes.

effects within a short latency period, these are predominantly subclinical effects and may likely be undetected except in a special investigation. A few studies, occurring mainly in an occupational setting, have demonstrated a higher incidence of clinical thyroid diseases or related delays in neurological development in childhood, associated with environmental exposure. Thus, to identify potential health risks of thyroid active compounds in communities, epidemiological studies, including effect monitoring and human biomonitoring, are necessary. To overcome these limitations, Dr. Karmaus proposed the development of a network of exposed communities concerned about exposures. In addition to a representative national sampling, a network would provide assessments of exposures and health outcomes with different communities mutually serving as exposed and control groups. Residents of communities that participate in epidemiological studies are all too often subsequently neglected in the dissemination of information about the risks identified. Such a network could foster risk communication and prevention within communities where studies have been conducted.

The second paper, by Dr. Matthew Longnecker, concerned the etiology of diabetes within communities. The rates of both type 1 and type 2 diabetes mellitus have been increasing in the U.S. and elsewhere, and genetic factors account for less than half of the new cases. These observations suggest that environmental factors cause both type 1 and type 2 diabetes. Occupational exposures have been associated with increased risk of diabetes. In addition, recent data suggest that toxic substances in the environment, other than viruses or immunogenic dietary components, are associated with the occurrence of type 1 and type 2 diabetes. For type 1 diabetes, intake of nitrates, nitrites, and N-nitroso compounds have been associated with increased risk. Overall, however, the data were limited and inconsistent. With respect to type 2 diabetes, data on arsenic and 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) in relation to risk were suggestive of an association but were inconclusive. The occupational data suggested that more data on exposure to N-nitroso compounds, arsenic, dioxins, talc, and straight oil machining fluids in relation to diabetes would be useful. Dr. Longnecker concluded that although environmental factors other than contaminants may account for the majority of type 1 and type 2 diabetes, the etiologic role of

several contaminants and occupational exposures deserves further study.

The third paper, by Dr. Helen Tryphonas, Health Canada, concerned diseases of the immune system. Experimental animal studies indicate that environmental contaminants can have adverse effects on several organs and tissues of the immune system. Such effects are known to lead to increased host susceptibility to microbial infections and compromised immunosurveillance mechanisms that are normally instrumental in the elimination of neoplastic cells and the prevention of autoimmune diseases. Evaluation of the potential risks that environmental contaminants pose to the human immune system is currently accomplished via extrapolation of experimentally derived animal data to human. This process requires that uncertainty factors, such as interspecies differences and genetic variability, be taken into consideration. This process would be more manageable if data similar to that derived from experimental animals were available for human populations exposed to environmental contaminants. In view of the continuous exposure of humans to environmental contaminants there is, presently, a pressing need to improve the process of risk assessment by enlarging the human data base. To generate the much needed data, one must first identify a set of clinically relevant endpoints. Such endpoints, when adequately standardized, should be incorporated into the design of prospective epidemiologic studies.

While all three endpoints have potential to be used in these ways, there is still a need for developmental work and, if they are validated, make them operational.

Issues of Economic Costs of Disease and of Equity

The Work Group on Ecosystem Health had an interest in the direct and indirect economic costs of diseases that might be associated with exposures to pollution. In the field of economics there is extensive work being undertaken on this topic. Tom Muir of the Ontario Region of Environment Canada chose the following four candidate health outcomes for analysis: diabetes; Parkinson's disease; hypothyroidism; and deficits in IQ.

The methods used involve the examination of several lines of evidence, including empirical, methodological and theoretical. First, the literature was reviewed to determine the evidence leading to the published concerns that exposures to environmental agents, particularly persistent toxic substances, are plausible risk factors to children, and the chosen effects or outcomes. Second, literature was reviewed to gauge and assess the extent to which approaches and methodology to measure such financial and economic costs and impacts, in general, are developed, and the extent to which case studies on our chosen outcomes have been undertaken. Where such

> . . . unlike research conducted to evaluate drugs, those responsible for environmental exposures to potentially toxic chemicals neither survey those exposed for their consent, nor provide an appropriate calculus for measuring risks and benefits.

methodologies and case studies existed, they were either cited, adapted, updated or expanded. Third, where no existing studies were found that evaluate or cost any of the selected effects, primary data sources were searched for, and where possible, estimates were made using the existing methodologies and/or economic theory. Throughout this exercise, efforts were made to develop estimates not only for Canada or the Canadian jurisdictions, but for the United States. In some cases, there are cost estimates for other countries, in the literature, and these are cited for comparison.

Based on these several lines of evidence, there are indications of an enormous cost burden for these diseases or conditions in the United States, Canada and elsewhere. Tom Muir reviewed actual social and economic costs, constructed estimates of some costs from pertinent sources, and provided several hypothetical examples that are consistent with published evidence. Many detailed costs are estimated, but these are fragmented, and missing in coverage and jurisdiction. Nonetheless, the cumulative costs identified are potentially very large and undoubtedly extend into the billions of dollars.

In the United States, environmental justice, concerned with equitable representation of all affected persons, particularly low-income people and persons of color, in environmental and environmental health decision-making, has become a prominent political issue. Dr. Rueben Warren of the Center for Disease Control and Prevention drew attention to the Presidential Executive Order 12898, on environmental justice, which encourages all federal agencies to ensure environmental justice in their policies, regulations and programmatic activities. People in communities across the country experience adverse living and health conditions due, in part, to the limited implementation of the Executive Order. Adverse health conditions associated with environmental toxins are a major problem expressed by environmental justice advocates and people living in close proximity to toxic and hazardous waste sites. They perceive a disproportionate burden of disease, dysfunction and premature death due to chemical contamination. They also believe that public health officials have not adequately responded to their health concerns. Dr. Warren discussed the history and current activities of the

environmental justice movement and described human health threats posed by toxic and hazardous wastes. He reviewed strategies for collaboration between environmental justice advocates and public health officials that, if implemented, should enhance the missions of both groups. More importantly, it is expected that through increased basic and applied research and public health advocacy and practice, the well-being and quality of life of low-income and people of color will improve.

Dr. Bernard Weiss of the School of Medicine and Dentistry at the University of Rochester, contrasted the ethical requirements for conducting experimental studies on drugs in humans with those for populations exposed to environmental contaminants. Drug testing in humans is governed by a body of principles whose main tenets have evolved over the past few decades. Three of these tenets provide the foundations for judging the ethical adequacy of such an experiment. One addresses the question of who receives the benefits of the research and who bears its burdens. A second requires that the research maximize the potential benefits to the subjects and minimize the risk of harm. The third concerns the source of guidelines for informed consent and requires that subjects enter into the research voluntarily and with adequate information. By contrast, unlike research conducted to evaluate drugs, those responsible for environmental exposures to potentially toxic chemicals neither survey those exposed for their consent, nor provide an appropriate calculus for measuring risks and benefits. Dr. Weiss concluded that a process of ethics assessment may need to be incorporated, as a new element, into risk characterization, especially for exposure to developmental neurotoxicants, where the risk-benefit incompatibility between different populations can be so striking.

Contrasting the Scientific Approach and the Public Health Approach

The Great Lakes Science Advisory Board noted that there has been a significant debate recently about decision making in relation to the protection of public health. Mr. Horace Krever headed a commission into a major public health disaster in Canada from the presence of HIV and hepatitis-C in the blood supply. The findings from the judicial investigation of the blood supply disaster may have important lessons for those involved in policy making under the Agreement. Specifically, pollution of the Great Lakes with persistent toxic substances may present several analogous situations.

Mr. Krever pointed out that a chief factor leading to the infection of so many people with a deadly virus was the influence of the traditional way of thinking of the scientists, when what was more appropriate was the method of the public health practitioners. He noted that there are essential differences between the scientific approach and the public health approach. The former was characterized by a refusal to accept that the illness could be spread by blood until Koch's Postulates had been satisfied and this lead to lengthy and undue delays in introducing the screening of blood donors and the subsequent testing of blood donations. The absence of definitive proof of a link between AIDS and blood transfusion was consistently used as a justification for maintaining the *status quo*. Strong action to reduce the risk of AIDS should not have required conclusive evidence. If there was even a possibility of transmission of the virus via blood, there was, above all, a moral and legal obligation to protect the blood recipient. Where there is reasonable evidence of an impending threat of public health it is inappropriate to require proof of causation beyond a reasonable doubt before taking steps to avert the threat.

Mr. Krever noted that, in environmental matters, this precautionary principle has become part of a number of international treaties and declarations, including the Second and Third International Conference of the Protection of the North Sea concerning ocean dumping. The application of the precautionary principle is not problem free. First, on some occasions, it will turn out after the fact that precaution was, with the benefit of hindsight, not necessary, and moreover, was costly. The second problem relates to the application of cost-benefit analysis that should not be a deterrent in the application of the precautionary principle. Risk management is defective if it protects only the risk creators and permitters and not also the person suffering the harm when inevitably the risk accrues. For these circumstances, there should be no fault compensation for victims of the harm created by the risk. The compassion of the society can be judged by the measure it takes to reduce the impact of the tragedy on its members.

Mr. Krever concluded by posing several questions. What should we as a society do about polluters, and about pollution? Should we shut down the polluter's business and so create unemployment by making them undertake preventive measures that are so cost prohibitive that their businesses become unprofitable? Or do we simply warn consumers of the products poisoned by the pollution? More philosophically, what right do we have, as the current and very temporary trustees of the environment, to decide, even for apparently sound reasons, to permit the destruction of land and water?

Conclusions

Epidemiological data on incidences of mortality, morbidity as hospitalization, congenital anomalies and infant mortality are useful to detect gross differences in rates between communities that might be related to pollutants. On the basis of epidemiological data and statistics on health endpoints that might be related to exposures to pollutants, there are several Areas of

Concern that have elevated incidences of diseases. Similarly, research on wildlife populations for exposure and disease has provided exposure and effects information that is directly relevant to research on human health.

Local health authorities have well developed institutional structures for preventing diseases caused by microbiological agents and for investigating and responding to disease outbreaks. In contrast, there is a generalized reluctance at all levels of government to detect and publicly acknowledge anomalous incidences of diseases and disorders within communities that may have been caused by chemical pollutants, and there seems to be an apparent aversion to establishing the necessary institutional health structures at the local and regional levels that can effectively investigate and respond to community health crises that may be caused by chemical pollutants.

There is growing evidence of an increase in learning, behavior and developmental problems in the North American population. Exposure to persistent pollutants may contribute to this situation by their actions on physiological functions, and in particular the neuro-endocrine axis. While these may not be readily apparent in the individual, they can have important effects on a population level. There is a priority to address these questions through:

- tracking, monitoring and surveillance using registries, hospitalization, school performance records, and use of pharmaceutical utilization data; and
- integration of data bases on exposure assessment, health, and academic and behavioral performance indicators.

Research Needs

The SAB has identified the following specific research needs concerning community health:

- to examine the subtle decrements in neurofunctional capacities, immunological, hormonal and reproductive functions in relation to exposures in adult and child populations;
- to determine whether subtle functional decrements in wildlife reduce survival, growth and population numbers of wildlife;
- to use the new information on the human genome to evaluate how genetic susceptibility explains human responses to environmental pollutants and help identify the more sensitive sub-populations that may need additional consideration in the development of regulations and regulatory actions;
- to investigate interrelations between exposure and the socio-economic environment with a view toward better policy making;
- to develop methodologies that will allow for better integration of information from exposure, health and social data sets, and to develop more effective means of applying animal experimentation and wildlife studies to humans; and
- to assess the impact of the biological effects resulting from chemical exposure on community well-being.

2.2.2 Protecting Human Health from Exposure to Contaminants in Great Lakes Fish

Introduction

Fish in the Great Lakes basin are contaminated with a variety of persistent toxic substances and this raises concerns about the suitability of fish as food. In the past 30 years, agencies responsible for public health and for fisheries have had to respond to the challenge of maintaining the recreational use of the Great Lakes fisheries resources while protecting public health from exposures to persistent toxic substances. Governments have responded to this challenge by publishing advisories on the consumption of Great Lakes fish. For example, in Ontario, there is a *Guide to Eating Ontario Sport Fish*, published and distributed annually to anglers, particularly through the Liquor Control Board of Ontario and outfitters selling fishing licenses. For the past decade, the Council of Great Lakes Governors has convened a Great Lakes Fish Advisory Task Force to develop a common protocol for an advisory for contaminants in fish across all the Great Lakes states. Fish consumption advisories have been based on the estimation of 'safe' concentrations of each contaminant based on toxicological data. Toxicology experiments have traditionally been undertaken at high dosage concentrations, and the safe concentrations have been estimated by applying safety factors to the dosage at which there was no effect observed. It has been assumed that the public would be protected as long as the concentrations in the Great Lakes fish that were being consumed were below these concentrations. As the IJC pointed out in its Tenth Biennial Report on Great Lakes Water Quality, fish consumption advisories are not a guarantee of safety and for more than the past 30 years, fish advisories have generally become more restrictive as knowledge increased and more sensitive endpoints were reported from human health research.

Risk Assessment and Limitations

In 1983, the U.S. Environmental Protection Service introduced a formal risk assessment process that has been widely applied to the setting of 'safe' concentrations for consumption

of Great Lakes fish. The current advisories are based on a series of assumptions, including:

- the risk can be defined;
- the critical variables to be managed can be identified; and
- specific actions and techniques are available and effective for achieving management goals.

Most Great Lake jurisdictions include consideration of the species consumed, intervals of consumption, quantities consumed, cooking methods, location caught, size of fish and exposure of sensitive populations. There is, however, always a danger that current advisories do not reflect the latest research.

For example, in 1990, the endocrine disruptor hypothesis was proposed (Colborn and Clement, 1992; Colborn et al. 1993). The thesis is that structural and functional developmental processes, such as differentiation of the reproductive anatomy and of neurological and immunological processes, is under the control of a large variety of chemical messengers. These include, not only the traditional hormones from glands, but also various growth factors, interleukins and cellular receptors, collectively known, for the purposes of this hypothesis, as the endocrine system. The mechanism of control action of these chemical messengers is through interactions at receptor sites and turning specific genes on or off at predetermined periods of development. The products from these genes in turn affect other cellular processes, such as cell division or cellular differentiation. The concentrations at which these chemical messengers operate are at fractions of a trillionth of a gram.

Certain natural and man-made chemicals can interfere with the production, transport and metabolism of these chemical messengers, or they can mimic or block the chemical messengers at the receptor sites. These interferences with the endocrine system can result in irreversible alterations to a wide variety of developmental processes, including the reproductive anatomy (Gray et al. 1999), the neurological (Colborn et al. 1998) and immunological (Voccia et al. 1999; Colborn 1995; Porter et al. 1999) systems. These natural and man-made endocrine disruptors are at concentrations much higher than the concentrations of the chemical messengers that control developmental processes. They are not necessarily bound to carrier proteins that moderate the endocrine activity of the normal hormones. In traditional toxicology, the effect becomes more pronounced as the dose or concentration of the compound increases yielding a monotonic relationship. However, the dose-response relations with endocrine disruptors tend to be non-monotonic.

Though this is a well-established phenomenon in endocrinology, it has not been a general consideration in traditional toxicology. On October 10-12, 2000, at the request of the U.S. Environmental Protection Agency, the National Toxicology Program and the National Institute of Environmental Health Sciences organized and conducted a scientific peer review meeting to evaluate reported low-dose effects and dose-response relationships for endocrine disrupting chemicals. The participants were from a variety of interests including industry and environmental non-government organizations. For this meeting, 'low-dose effects' referred to biological changes that occur in the range of human exposures or at doses that are lower than those typically used in the U.S. EPA's standard testing paradigm for evaluating reproductive and developmental toxicity. The Statistics and Dose-Response Modeling Subpanel analyzed the data for 38 studies prior to the meeting and provided its analyses to the four other subpanels on: Bisphenol A; Estradiol and other estrogens; androgens and antiandrogens; biological factors; and study design.

Based upon presentations by the individual subpanels and general discussions during the plenary session, preliminary conclusions from this peer-review meeting include the following.

- Low-dose effects have been clearly demonstrated for estradiol and some estrogenic compounds. For example, low-dose findings for nonylphenol and the phytoestrogen genistein include effects on the immune system and on neurological structure.
- Effects of antiandrogenic compounds have been demonstrated for some endpoints and the dose-response curve appears linear to the lowest dose tested; however, it was noted that the available studies were not designed to evaluate low-dose effects as defined for this review.

Workshop participants identified areas for additional research that would clarify uncertainties about the occurrence of low-dose effects and better characterize those observed effects. These include using pharmacological and genetic approaches to determine mechanisms of action and

to characterize dose-response relationships, characterizing response longevity from gestation through adulthood, evaluating long-term health outcomes, investigating the basis for immune system effects, and determining the impact of variations in endogenous hormone levels. The implications of these irreversible low-dose phenomena, particularly for community health, are far reaching and the main consideration is that very low concentrations of these substances cause endocrine disruption, and humans should not be exposed to them. The final report of the National Institute of Environmental Health Sciences' Endocrine Disruptor Low-Dose Peer Review has been released for public comment and is posted at http://www.ntp-server.niehs.nih.gov/htdocs/liason/LowDosePeerFinalRpt.pdf.

There is a wide array of documented effects in humans, wildlife and in experimental animals in the laboratory. In several populations, there have been increased rates of testicular and prostate cancer, cryptorchidism and hypospadias, and decreases in sperm quality (Toppari et al. 1996; Swan et al. 1997). Recent epidemiological studies have shown that women who ate Lake Ontario fish for seven years prior to pregnancy had shorter menstrual cycles (Mendola et al. 1997) and maternal consumption of Lake Ontario fish for three to six years was associated with a reduced biological capacity to reproduce (Buck et al. 2000). Similarly, an epidemiological study of anglers and their families found an association between the amount of sport-caught fish consumed by males and a delay in conception (Courval et al. 1999). Consumption of contaminated fish from the St. Lawrence River has been associated with a decline in short-term memory, attention and fine motor skills in adult fisherfolk (Mergler et al. 1997; 1999). Similar findings have recently been published that show the impact of PCBs and other fish-borne contaminants on intellectual functioning in older adults who ate more than 24 lbs. per year of sport fish caught in Lake Michigan (Schantz et al. 2001). There are many chemicals in Great Lakes fish that have been shown to be endocrine disruptors, including DDT and metabolites, PCBs and dioxins. More particularly, there are increasing Great Lakes concentrations of brominated organic flame retardants that are endocrine disruptors, such as polybrominated biphenyl ethers (Darnerud et al. 2001). In addition, there are many modern pesticides in use that are endocrine disruptors and to which the population in the Great Lakes basin is exposed.

Of particular concern are the effects on the developing brain. For example, in a cohort of infants established in 1980, maternal consumption of Lake Michigan fish prior to and during pregnancy was associated with the following effects associated with exposure *in utero* to PCBs: poorer performance in tests of visual recognition memory in infants (Jacobson et al. 1985); poorer verbal and numerical memory in four year old children (Jacobson et al. 1990); and a loss of more than six IQ points by the time the children had become 11 years old (Jacobson and Jacobson, 1996). Ten years later, the results were replicated in another cohort of infants established in 1990, some of whose mothers had eaten Lake Ontario fish prior to pregnancy (Lonky et al. 1996). The effects were most pronounced in infants who were most exposed to the higher chlorinated PCBs, and included an inability to habituate to unpleasant events (Stewart et al. 2000). Subsequent studies at six and at 12 months showed poorer performance in intelligence tests in those children with the highest PCB levels (Darvill et al. 2000). Though these neurological effects are statistically robust, there have been questions about whether they are biologically significant since the shift downwards in scores is within two standard deviations of the mean and thus not outside the lower 95 percent confidence limit for the population. Should these statistically significant losses be regarded as adverse biological effects? It would seem that no community or civilization, and particularly one that is so highly dependent on the collection and processing of information, can afford the systematic loss of neurological functioning (Weiss 1997).

Studies of several different human populations exposed to PCBs before birth, suggest that prenatal exposure results in a reduction of overall IQ of six to eight points, and other studies show motor and sensory decrements upon pesticide exposures. While this may not be a sufficiently large decrement so as to greatly influence any single individual's lifetime productivity, on a population basis this may exert very important societal effects.

Studies of several different human populations exposed to PCBs before birth, suggest that prenatal exposure results in a reduction of overall IQ of six to eight points, and other studies show motor and sensory decrements upon pesticide exposures. While this may not be a sufficiently large decrement so as to greatly influence any single individual's lifetime productivity, on a population basis this may exert very important societal effects. Most human populations are never exposed to a single toxic substance, and indeed Great Lakes fish contain many different chemicals. However animal studies of single chemicals, such as PCBs, methyl mercury and persistent pesticides, alone or in combination, or animals being fed contaminated fish, all confirm alterations in brain function consistent with reduced intelligence, a shortened attention span and increased frustration.

The new information about endocrine disruptors poses several questions in relation to traditional risk assessment. Can 'safe' concentrations of these compounds be determined from traditional toxicology testing at high doses? Did the application of traditional toxicological approaches to derive 'safe' levels for compounds, that are now known to be endocrine disruptors, lead to injury to human health even in those who followed the fish consumption advisories? Where there is a possibility that injury may occur, is it essential, in the interest of public health and safety, that responsible parties be identified and empowered to take appropriate direct action to avoid, prevent or mitigate future harm? Might abrogation of this responsibility, by responsible parties in matters related to public health protection, result in findings of liability, negligence and even criminality by the courts or in official inquiries, such as the Krever Commission? Where the consequences are serious, would decision makers be held accountable for adopting policies, programs and practices that were not risk averse, and that promoted safety, instead of precaution? Are the scientific uncertainties of such a degree that the general public should be warned not to eat any fish from the Great Lakes or the St. Lawrence River, until remedial actions have reduced the concentrations to levels at which effects on the endocrine system and on developmental processes do not occur?

Risk Management

Fish consumption advisories have been described (Knuth 1995) as a "risk management tool designed to inform fish consumers about how to minimize exposures to chemical contaminants." Other risk management tools have been implemented in the past, including closure of commercial fisheries and the mid-1970s prohibition by New York state of the possession of certain sport fish from Lake Ontario. This last means was met with such flagrant violation of the law that the regulation was rescinded within months of proclamation. The objective in developing fish consumption advisories has been to give people enough information to make their own decisions about how much Great Lakes fish to eat and their likely exposure to persistent toxic substances through consumption of fish.

The development and implementation of the risk management program for consumption of fish from the Great Lakes is based on the following premises:

- the principal route of human exposure to persistent toxic substances in the Great Lakes region is through the food chain;
- there is a significant body of scientific research related to understanding human health effects from eating Great Lakes fish;
- implementation of remedial work will lead to declines in the concentrations of persistent toxic substances in fish; and
- fish consumption advisories must be based on assessing risk based on the most sensitive end points and to the most sensitive subpopulations.

There is a significant body of evidence that, for example, neurological effects from prenatal exposure to PCBs may be the most sensitive endpoint, and women of child-bearing age and children may be the most sensitive subpopulations. For these reasons, risk management, in the form of fish consumption advisories, is not necessarily uniform for the entire population. Based on scientific research, risk managers might communicate different advice to different age groups ranging from unlimited fish consumption, to complete avoidance.

Risk Communication

The success of any risk management approach depends on effective risk communication. This, in turn, requires that there is not only agreement on a clear message to be communicated, but also appropriate methods for communicating that message. In the past, the states and provinces each issued fish consumption advisories applicable to the fish caught in their jurisdictions. Because of differences in the approaches used by the jurisdictions to calculate acceptable exposures, the resulting advice might differ between jurisdictions. In the mid-1980s, there was a growing concern that advice in some jurisdictions was less protective of the public and sensitive subpopulations and this lead to confusion for the general public. In an effort to address this inconsistency, the Council of Great Lakes Governors convened a Great Lakes Fish Advisory Task Force to develop a common protocol for an advisory for PCBs across all the Great Lakes states. However, this effort took nearly 10 years of scientific review and negotiations before completion in 1995, and no other common advisories have been developed for any other persistent toxic substance.

There has been extensive social science research undertaken on the effectiveness of communication of the fish consumption advisories and much of this has been reviewed by Grondin and LaRue (http://www.hc-sc.gc.ca/ehp/ehd/catalogue/bch_pubs/great_lakes_part2.pdf). For example, early work among New York state anglers indicated that those who were older, more educated, higher income, male and white had a higher awareness of the advisories (Connelly et al. 1993). Overall knowledge on the adverse health effects of fish consumption was high, though knowledge of the recommendations in the advisories tended to be inaccurate. While dissemination of the information through brochures distributed with fishing licences is an effective means of communicating the message to certain groups, there are many subpopulations, such as women and certain ethnic groups, who were not being reached (Knuth 1995). Programs have

been developed to communicate more effectively with these groups. A more recent survey has shown the scale of Great Lakes fish consumption (Tilden et al. 1997). In the eight Great Lakes states, about 4.7 million people eat Great Lakes fish, and women accounted for 44 percent of these Great Lakes fish consumers. This study confirmed the results from the previous work, that women tended to have a poor awareness of the advisories, suggesting the need for special risk communication strategies.

There are difficulties in obtaining similar statistics for Canadian angling in the Great Lakes, because no comparable random survey has been undertaken. There is one estimate from the mid-1980s that 37 percent of the general population of Ontario (about 10 million people) participated in sportfishing an average of five times per person per year (Usher et al. 1987). A survey by the Department of Fisheries and Oceans (1997) showed that there were 1,928,568 licenses issued in 1995, of which 1,342,567 were to Ontario residents. Instead of a random sampling approach to estimate the number of anglers in the province, Health Canada (1997), through its former Great Lakes Health Effects Program, undertook a Fish and Wildlife Nutrition Project as a series of surveys of anglers at the following five Great Lakes Areas of Concern: Metro Toronto; St. Clair River; Detroit River; Hamilton Harbour; and the Niagara River (http://www.hc-sc.gc.ca/ehp/ehd/catalogue/bch_pubs/monograph.pdf).

There is no specific requirement that the fish consumption advisories reflect current research results. While public and private efforts throughout the basin promote the consumption of Great Lakes fish, research undertaken in the past decade continues to raise serious public health questions about the harmful effects of exposures to persistent toxic substances. While these forces tend to minimize the risk detailed under current fish advisories, new research suggests that many of the current advisories are set at much too high a level, and do not adequately protect public health. If these questions escalate among the public into serious concerns about health, there is the potential for widespread dissatisfaction with the fish consumption advisory approach. As understanding of the toxic effects of exposures to persistent toxic substances increases over time, a transparent and accountable process for updating the advisories with current scientific understanding of health effects is needed.

In the case of other highly exposed groups, such as ethnic and native subsistence consumers who choose to exceed or ignore the recommendations of the advisories, they assume a risk that is accordingly higher than would otherwise be the case if the advisory were to be followed. In order to reduce the risk to this group to within a no observable effects level assumed by the advisories, it is necessary to improve communication and understanding, sufficient to support a modification of behaviour that respects the advisory. Recent social research is only beginning to identify the important elements of a risk communication strategy to better convey information to support improved personal decision making.

Because of the serious public health implications already acknowledged from consuming Great Lakes fish, and the complex scientific issues related to the significance of new findings from the latest scientific research on human health effects, the SAB recommends that the task of reviewing and developing a uniform, protective advisory be undertaken on a scientific basis by a third party, with adequate human and financial resources provided by the governments to achieve a rigorous and credible result.

2.2

Recommendation

Accordingly, the SAB recommends the following to the IJC.

- **Recommend to the Parties that the U.S. National Academy of Sciences and the Royal Society of Canada convene a binational committee to develop a uniform and consistent protocol to protect human health from contaminants in Great Lakes fish.**

Given insufficient progress on this matter to date, the conduct of such a study should give consideration, but not necessarily be restricted to the following issues:

- the application of the latest health effects research in risk assessment calculations and the development of a process to include new findings;
- the use of a safety factor above and beyond the risk assessment calculation to ensure protection for the range of human responses to toxins, for potential synergistic effects of multiple toxic exposures, for effects not yet fully quantified, and protection of subpopulations at greater risk than the target population, particularly children;
- the improvement of risk communication efforts, particularly to protect sensitive populations, for example, subsistence anglers; and
- the identification of risk communication challenges, including the key factors related to perception and awareness that affect changes in attitudes and fish consumption behaviour.

2.3 WATER QUALITY ASSESSMENT AND REPORTING

2.3.1 Review of Annex 1 of the Great Lakes Water Quality Agreement

Introduction

In fall 1999, the Work Group on Parties Implementation began work to obtain newly released data from U.S. EPA's Lake Michigan Mass Balance (LMMB) project and compare these data to Specific Objectives in Annex 1 of the Agreement.

Review of the available data showed that only two of the compounds included in the LMMB project, mercury and trans-nonachlor (a component of chlordane), are comparable to Specific Objectives in Annex 1. More importantly, the data revealed that concentrations of these two compounds in the open lake water column are approximately three orders of magnitude below the Specific Objectives.

While this could be viewed as good news, discussion within the work group and during a meeting with U.S. EPA officials managing the LMMB led to the conclusion that the Specific Objectives might not be stringent enough. For example, it was noted that while open lake mercury concentrations are far below the mercury Specific Objective, "we still have problems with mercury," such as widespread fish consumption advisories. Therefore, the task evolved into an examination of the Specific Objectives themselves.

Specific Objectives were incorporated into the Great Lakes Water Quality Agreement in 1978 and reflect the science and understanding of chronic and acute effects on human and aquatic ecosystem health prevalent at that time. Our understanding of cause and effect relationships, the nature of the threat posed by contaminants, and factors that impinge upon human and ecosystem health has improved considerably over the past quarter century.

Specific Objectives were incorporated into the Great Lakes Water Quality Agreement in 1978 and reflect the science and understanding of chronic and acute effects on human and aquatic ecosystem health prevalent at that time. Our understanding of cause and effect relationships, the nature of the threat posed by contaminants, and factors that impinge upon human and ecosystem health has improved considerably over the past quarter century. In addition, the information base about the environmental occurrences of these substances and programs in place for their regulation continue to evolve.

In keeping with the Commission's responsibility under Article VII of the Agreement, to tender "advice and recommendations to the Parties in connection with matters covered under the Annexes to th[e] Agreement" and to ensure that the Agreement remains strong and relevant, the work group decided to undertake a review of Annex 1.

A Proposal to the Commission

To secure the resources necessary to carry out this task, a white paper was presented to the IJC during its fall 2000 semi-annual meeting. The Commission subsequently allocated the resources.

The intent was to frame the issue as opposed to development of new or alternative Specific Objectives or other prescriptive solutions. To address the task, the work group commissioned the preparation of a background report and then convened a workshop where interested stakeholders could learn about the issue and share their opinions.

Background Report

Limno-Tech, Inc. of Ann Arbor, Michigan was chosen to prepare a background report, specifically to:

- compile the most current field data representative of open-lake conditions and compare those data with the Specific Objectives;
- compile current statutory, regulatory and policy values used by the United States and Canadian federal agencies, Great Lakes state agencies, and Ontario provincial government agencies to manage Great Lakes environmental quality and, where possible, compare those values with the Specific Objectives;
- summarize how each Great Lakes agency assesses compli-

ance with its set of statutory, regulatory and policy values; and

- summarize the conceptual basis and rationale for the development and application of each set of values from the second task above.

The report, which is posted on the IJC's web site at **http://www.ijc.org/agree/annex1/index.html**, was not intended to be a comprehensive review. Resource and time constraints were such that data were collected primarily from federal, state and provincial government sources. Data reviewed were limited to those reflecting the open waters of the lakes, though the Specific Objectives are not similarly limited in their application. Only data generated within the last five years were included and did not necessarily represent comprehensive spatial coverage. All data were assumed to meet the quality assurance/quality control requirements of the programs within which they were generated. Despite these limitations, the report provided sufficient information to allow judgments to be made about the currency and relevance of Annex 1.

Key information from the report follows.

Comparison of Environmental Data to Specific Objectives

The goal of this screening-level study was to make general comparisons of whether the data are less than, equal to or greater than the Specific Objectives. The statistical and environmental significance of any differences noted were not evaluated.

Concentrations of most Annex 1 substances are apparently below their Specific Objectives in all the lakes, both in the open lake water column and in fish tissue. Differences of an order of magnitude or more are common, especially for water column data.

The most significant exceedances that occur are for the fish tissue objectives. PCBs exceed the fish tissue objective in all takes by multiples ranging from approximately four in Lake Superior to almost 18 in Lake Michigan. DDT and its metabolites slightly exceed the fish tissue objective in Lake Michigan and approach it in lakes Huron and Ontario. Mirex, with a Specific Objective of no detection in fish tissue, is detectable in at least some fish in all the lakes. Lake Ontario has the highest frequency of detection and also the highest concentrations detected. All other lakes are relatively low on both counts.

Other apparent exceedances occur for guthion and unionized ammonia in Lake Erie. The detection limit for readily available parathion data is above the Specific Objective in some lakes.

Comparison of Regulatory and Policy Values with Specific Objectives

Regulatory and policy values (i.e. standards, criteria, guidelines) were reviewed for jurisdictions within the Great Lakes basin. Among the key findings are many inconsistencies both in terms of specific values and in terms of substances included. There are a number of Specific Objectives for which some or all of the jurisdictions examined have no comparable policy value. Conversely, there are many substances for which policy values exist, but for which there are no Specific Objectives. The closest correspondence, in terms of substances included and numeric objectives is with the Ontario Provincial Water Quality Objectives promulgated in 1979.

Specific Objectives based on water concentrations are often lower than policy values intended to protect aquatic life. However, water concentration policy values intended for protection of human or wildlife consumers of aquatic organisms are almost always orders of magnitude below the Specific Objective. For example, the Specific Objective for aldrin/dieldrin in water is 0.001 g/L. Ontario Provincial Water Quality Objectives and U.S. EPA Great Lakes Water Quality Guidance values for protection of aquatic life are 0.001 and 0.056 g/L, respectively. However, the Water Quality Guidance value for protection of humans exposed through fish consumption is 0.0000065 g/L, almost three orders of magnitude below the Specific Objective.

Where there are regulatory or policy values to compare with the various fish tissue-based Specific Objectives, the Specific Objectives are not the lowest values in any instance. However, the discrepancies tend to be less than for water-based values, with very few even as large as an order of magnitude. For example, the Specific Objective for aldrin/dieldrin in edible fish tissue is 0.3 g/g (wet weight). The comparable policy values for the U.S. FDA (commercial fish sales) and the states of Michigan and Ohio (trigger levels for fish consumption advisories) are 0.3, 0.3 and 0.05 g/g, respectively.

Monitoring and Compliance Assessment

The effort to compare environmental data to the Specific Objectives focused primarily on data available from government agencies. Attempts were made to obtain data for comparison to 37 Specific Objectives (open lake water column and/or fish tissue) in each of the five lakes, a total of 185 comparisons. In 73 instances, 40 percent, data could not be obtained because no agency contacted does the appropriate monitoring. Monitoring programs at the state and local level tend to be aimed at nearshore areas, particularly Areas of Concern. Much effort is being directed by the various jurisdictions toward assessing fish tissue levels and the impacts of contaminated sediment in the Areas of Concern.

The effort to learn about how the jurisdictions judge compliance with their own regulatory or policy values was intended to provide insight into how achievement of the Specific Objectives might be determined, as required by Article IV of the Agreement. The finding was that none of the agencies contacted has a formal program in place to judge compliance with its policy values. There are some informal efforts undertaken by Environment Canada but there is no formal reporting. U.S. EPA does not presently systematically review open lake water quality data or compare the data to U.S. EPA Great Lakes Water Quality Guidance or other criteria. States and provinces similarly do not have formal programs for judging compliance with their regulatory or policy values.

Workshop

A workshop titled *Review of Annex 1 of the Great Lakes Water Quality Agreement* was held in Ann Arbor, Michigan on March 21, 2001. Approximately 40 attendees heard a series of presentations on the history of Annex 1, the background report, the science of standard setting and the science of compliance assessment. These presentations were followed by an 'options panel' with representatives from the two Parties, industry and the environmental community. A plenary discussion followed. The panel and subsequent plenary discussion focused on the following questions:

- Is Annex 1 still relevant and useful? Why or why not?
- Should Annex 1 be revised? If so, how?
- Is there a role for ecological indicators (for example, SOLEC) in the Agreement?
- How should achievement of Specific Objectives be judged?

The following are significant highlights from the workshop. The full workshop transcript is posted on the IJC's web site at **http://www.ijc.org/agree/annex1/index.html**.

History of Annex 1

Dr. Joel Fisher of the IJC's U.S. Section explained that Annex 1 was part of the original Agreement signed in 1972. It contained 'final' objectives for eight substances and 'interim' objectives for five substances or classes of substances. The objectives were based, at least in part, on criteria and objectives in place in other jurisdictions at the time. Most of the Specific Objectives currently in place were added when the Agreement was revised in 1978, taking advantage of extensive studies in both countries and elsewhere into contaminant effects culminating, for example, in the development of water quality criteria mandated by the 1972 U.S. Clean Water Act. The 1987 Protocol to the Agreement added the Supplement to Annex 1 but did not add or change any Specific Objectives.

Issues Raised by The Background Report

Wendy Larson, Limno-Tech, Inc., reported the findings in the background report as summarized above. Dr. Joseph DePinto, also of Limno-Tech, Inc., discussed some issues that arose during the study.

Variations between agencies in sampling and analytical protocols made it difficult to put all the data on a common footing to allow fair comparisons with the Specific Objectives. There was also variation in the way data were provided. Some agencies provided raw data and some provided averages. Handling of censored data (for example, non-detects) when computing averages also varied among agencies. The contractor noted internal inconsistencies for some substances that have both water and tissue Specific Objectives. That is, given current knowledge of bioaccumulation factors, the tissue concentrations are not consistent with what would be expected to occur in fish bioaccumulating the substance from water at the specified concentration.

When considering regulatory and policy values, Limno-Tech, Inc. noted that the Canadian Water Quality Guidelines cover 54 more substances than are included in the Specific Objectives. The U.S. EPA Great Lakes Water Quality Guidance covers 11 extra compounds. Those states that have chosen to implement the Great Lakes Water Quality Guidance's Tier 2 methodology potentially have policy values for hundreds of substances not included in Annex 1. It was also noted that unlike policy values from the various basin jurisdictions, the conceptual basis for the Specific Objectives is not always clear. For example, it is not always clear what is being protected and at what level.

The Science of Standard Setting

James Whitaker, EA Engineering, Science and Technology, reviewed the current approach to setting water quality policy values. He pointed out that there are three aspects to any value — magnitude, duration and frequency. To the extent the current Specific Objectives were based on early U.S. water quality criteria, they may incorporate this philosophy, but certainly not explicitly.

Mr. Whitaker said that careful consideration must be given, when setting water quality objectives, to the following issues.

- What is to be protected (e.g. species, designated uses, geographic range)?
- What level of protection is to be afforded?
- What is the true exposure to the substance?
- What data are available to support setting an objective?

The Science of Compliance Assessment

Article IV of the Agreement says, "The determination of the

achievement of Specific Objectives shall be based on statistically valid sampling data." Dr. Abdel El-Shaarawi of Canada's National Water Research Institute illustrated through a series of examples why, when setting and judging achievement of water quality objectives, it is important to consider the statistical nature of the variables involved. He pointed out that 'absolute' objectives, those stated as a single value not to be exceeded, present the most difficulty for judging achievement, though techniques do exist to do so if sufficient monitoring data are available.

The Options Panel and Plenary Discussion

A panel of experts from the Parties, industry and the environmental community was followed by a plenary discussion. The presentations and discussion elicited a wide range of ideas and suggestions. The following describes the range of ideas presented. Two points upon which there was very little disagreement were that the Specific Objectives are of little use because they are so out of date and that the situation should be remedied somehow.

Douglas Spry of Environment Canada made the important point that to be meaningful, the Specific Objectives need to drive management actions. During the plenary discussion this point was reinforced numerous times. He also made the equally important point that revision of Annex 1 will require political will and resources. Again, this point was validated during discussions. Among suggested options during his presentation were to:

- adopt new Specific Objectives from the existing pool of the Parties' current objectives (i.e. Canadian Water Quality Guidelines and U.S. EPA Great Lakes Water Quality Guidance);
- provide guidance in Annex 1 on use of the Parties' existing objectives, but do not incorporate them into the annex.; and
- revise and develop new objectives using the current science. During the discussion, several people made the point that this would be a very resource intensive task.

Paul Horvatin of U.S. EPA was clear that his agency has no formal position on revision of Annex 1. However, he pointed out that a new Annex 1 could be relevant and useful in a number of regulatory and environmental management contexts. He suggested an *action level* approach wherein Specific Objectives would be triggers for actions. For example, the Specific Objectives could be the most stringent of the various values in use in the basin. Apparent exceedances of the objectives would trigger binational consultation on what actions to take.

George Kuper of the Council of Great Lakes Industries stated that CGLI has reversed its earlier position and now favours revision of Annex 1. The focus of such revision should be on the *doable* with recognition that, in the context of the virtual elimination of substances, "there is no such thing as zero." He stressed that insistence on the unattainable only leads to inaction. Among the suggestions he made were:

- Replace the current numerical Specific Objectives with a "directive to utilize the SOLEC indicators as the monitoring protocol and outcome-based measures that define the specific objectives of the Agreement." There was much discussion of this concept. There was recognition that the SOLEC process is driving formulation of indicators and associated monitoring that could definitely fit into Annex 1. Some people involved with the process expressed the belief that it may be premature to use SOLEC indicators in this way. Mr. Horvatin said that he would resist putting the SOLEC indicators per se into the Agreement.
- Incorporate into the Supplement to Annex 1 the Commission's Virtual Elimination Task Force definition of virtual elimination, ". . . defined as achieving an absence of injury, and achieving the goals of restoring and maintaining ecosystem health."
- Revise Section 1(b) of the Supplement regarding detection levels to read, "Substances not detected and determined to be *absent* as specified in this paragraph will be treated as *zero* for purposes of data analysis and assessment of progress toward virtual elimination."

During subsequent discussion of the second and third points, it was suggested that something not detected in water, but detected in fish tissue, should not be considered virtually eliminated from the environment. However, it was also pointed out that virtual elimination in the Agreement refers to inputs, not presence. It was also pointed out that detection limits are always going lower, so a non-detect today might be a detect tomorrow. Thus, treating non-detects as zero may not be an unchangeable declaration of virtual elimination.

Neil Kagan of The National Wildlife Federation stated that "virtual elimination should be paramount in any discussion of Annex 1" and that, for persistent toxic substances, Specific Objectives should not replace virtual elimination. He said objectives of zero should be considered. Subsequent discussion of this concept pointed out the practical difficulty of judging achievement of such a standard. It was suggested that failure to detect the substance might be

taken as a preliminary indication of achievement but that, as long as fish flesh concentrations were sufficient to warrant consumption advisories, achievement could not be declared even if the substance could not be detected in water. It was also suggested that zero objectives could be useful driving activities to reduce concentrations in various media, such as fish flesh and sediments. Mr. Kagan suggested that new chemicals such as dioxins, alkyl phenols and *endocrine-disrupting* chemicals should be considered for inclusion in Annex 1 and that indicators for source loadings might also be considered.

Other significant points raised during the plenary discussion are as follows

- Being able to make credible judgments about the achievement of meaningful Specific Objectives for the Great Lakes may help highlight problem areas in the basin more clearly than is being done now. This could be useful when trying to obtain resources with which to address the problems.
- When striving for lofty goals like those in the Agreement, it is important to have something like Specific Objectives by which to judge progress.
- Because there are references to the Specific Objectives in several Agreement annexes, revision of Annex 1 may require revisions elsewhere. While this is a daunting prospect for some, it may ultimately lead to other needed improvements in the annexes.
- To date, judgments of the status of achievement of SOLEC indicators have not been based on large amounts of data or rigorous statistical or environmental criteria but, rather, on best professional judgments and peer review.
- Our scientific understanding of the Great Lakes is not at a point where we can understand how all stressors interact to affect the health of the Great Lakes. This makes any attempt at setting Specific Objectives, whether they are chemical-specific or ecological indicators, inherently *provisional* until our scientific understanding improves.

Findings and Recommendations

Answers to the questions posed to the workshop participants are a convenient framework within which to present the significant findings and recommendations from this review. Following are answers to those questions based on what was learned during the review. Recommendations are also presented.

1. **Is Annex 1 still relevant and useful? Why or why not?** Annex 1 and the Specific Objectives are still very relevant as concepts. In Article II of the Agreement, the Parties state that the purpose is "to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem." To work toward this purpose it is necessary to have targets or tangible evidence that progress is being made and successes are being achieved. Without this kind of feedback, it could become difficult to sustain the level of effort that is called for to continue progress toward the purpose of the Agreement.

Annex 1 is not particularly useful as it exists now because the Specific Objectives are badly behind the times in terms of our understanding of the requirements for restoring and maintaining the ecosystem. The Specific Objectives drive no management actions. Almost no one is impressed to hear that current data indicate that most of the Specific Objectives are being met because it is far from certain that meeting them any longer represents a significant achievement in terms of the purpose of the Agreement. This is probably why monitoring programs have drifted away from the Specific Objectives. It simply makes no sense to devote resources to demonstrating achievement of an objective that is no longer meaningful in terms Great Lakes ecosystem protection. Annex 1 and/or the Specific Objectives are referred to throughout the Agreement (Articles I, IV, V, VI, VII and X and several annexes). To the extent the lack of utility of the present Specific Objectives carries over to those other parts of the Agreement, it could perhaps be argued that Annex 1 in its current state is actually worse than useless.

2. **Should Annex 1 be revised? If so, how?** The answer to the first part of the question is emphatically yes. Annex 1 could and should be one of the touchstones of the Agreement. Great Lakes managers should be able to refer to Annex 1 when deciding the directions or effectiveness of management actions taken for the benefit of the ecosystem. Revision of Annex 1 represents an opportunity to revitalize the Agreement and recommit to its purpose. It is a shame not to take advantage of such an opportunity.

There are two facets as to how any revision should be done. The first concerns logistics. This review is not the first time concerns have been raised publicly about Annex 1. Nevertheless, despite the Parties' commitment to "consult . . . at least once every two years . . ." regarding modification of Annex 1, little meaningful action has been taken. Based on the level of interest and expertise displayed at the workshop, the lack of progress is clearly not due to shortages in those areas. What is needed is a clear commitment by the Parties to start an open, accessible, transparent and inclusive effort to make Annex 1 a vital part of the Agreement that will help drive actions toward accomplishment of the Agreement's purpose. While the content of Annex 1 is ultimately a matter of agreement between the Parties, the best way to decide on that content is to actively engage all stakeholders in an open process that

. . . it is clear that Annex 1 should be revised in a way that makes it a useful management tool and enhances reporting and public accountability.

gathers all ideas and viewpoints before decisions are made. One example of a process framework that could be used to engage stakeholders regarding substantive revisions to Annex 1 is described in Effective Collaborative Processes on Sustainable Development and Environmental Policy - The Boulder Principles, published by the Council of Great Lakes Industries. http://www.cgli.org/positions.html

The second facet of the question concerns what specific changes should be made to Annex 1. The options panel and plenary discussion illustrated there are many interesting and sometimes conflicting ideas about what should be done. A one-day workshop is clearly not adequate to come to any firm conclusions as to what would be most appropriate. Indeed, this was never the intent of the review. Nevertheless, it is clear that Annex 1 should be revised in a way that makes it a useful management tool and enhances reporting and public accountability. Moreover, any revision should ensure that Annex 1 is not only brought up to date, but that it will continue to remain current and relevant into the foreseeable future. Because the Agreement is between the Parties, it ultimately falls to them to define a process by which all the ideas can be aired and a best path for revision chosen.

Recommendation

The SAB recommends the following to the IJC.

- **Recommend that the Parties initiate a transparent and inclusive process to revise Annex 1 to drive actions toward accomplishment of the Agreement's purpose.**

3. **Is there a role for ecological indicators, such as SOLEC, in the Agreement?** Yes, there is a role for ecological and other indicators in Annex 1. Indeed, the Supplement already contains two lake ecosystem objectives that are rudimentary ecological indicators. The fact that something is called an 'indicator' should not preclude its consideration as a Specific Objective. Any indicator that has a firm scientific basis, has an identifiable desirable level that is relevant to the purpose of the Agreement and can be measured, should be considered for inclusion as a Specific Objective. This does not mean all indicators meeting these criteria should become Specific Objectives or that all Specific Objectives should originate as indicators. Further, not all indicators need be designed to generate statistically valid data. It simply means that semantics should not preclude the addition of a Specific Objective that would be a useful addition to Annex 1.

4. **How should achievement of Specific Objectives be judged?** The first facet of the answer concerns monitoring. It is impossible to judge achievement of any Specific Objective without collection of appropriate environmental data. Current monitoring and surveillance activities are insufficient to allow such judgments for many of the Specific Objectives. As discussed above, this is at least partly because the existing Specific Objectives are of little use for indicating progress toward the purpose of the Agreement. Nevertheless, Annex 11 specifically calls for surveillance and monitoring activities "To provide definitive information on the location, severity, areal or volume extent, frequency and duration of non-achievement of the Objectives ..." With revised Specific Objectives should come a renewed commitment to monitoring and surveillance programs that can realistically allow judgments as to achievement of those objectives. Such a commitment could probably be met by a combination of modifications to existing programs perhaps with modest additional activities. The specific requirements would obviously depend on the nature of any revisions to Annex 1.

The second facet involves the statistical nature of the Specific Objectives and the data used to judge achievement. The Annex 11 language cited above in combination with the Article II requirement that judgments of achievement be based on statistically valid sampling data, lay out the basic requirements fairly well. Discussions at the workshop demonstrated that techniques do exist or could be developed to facilitate statistically sound judgments. Monitoring programs put in place to judge achievement of Specific Objectives clearly should take advantage of advances in statistics to make such judgments more credible. Designing and implementing monitoring and surveillance programs as part of a collaborative process presents an excellent opportunity to harmonize such programs and eliminate many of the inconsistencies and other problems noted.

Recommendation

The SAB recommends the following to the IJC.

- **Recommend that the Parties, in conjunction with revisions to Annex 1, design and implement binationally harmonized monitoring and surveillance that will allow statistically credible judgments regarding achievement of the Specific Objectives.**

2.3.2 Review of the Agreement

In its 1995-97 priorities report, pages 32 - 33, the Science Advisory Board reported that the rapid transformation of Great Lakes basin governance poses a challenge for the continuing relevance of the Agreement and its institutions. The governments themselves acknowledged that "the environmental challenges faced collectively by our people have grown in size and complexity, requiring strengthened collaborative action." The board identified a number of reports that, collectively, "represent a cogent analysis of the institutional opportunities and challenges facing the United States and Canada in the joint management and protection of the Great Lakes. Their analyses suggest that 25 years of binational experience is sufficient for undertaking institutional reform ... to support continued progress under the Agreement ..." The board noted that, "Following release of the IJC's next [Ninth] biennial report, Article X of the Agreement calls on the Parties 'to conduct a comprehensive review of the operation and effectiveness of this Agreement'." The board then recommended the following to the IJC and continues to do so.

Recommendation

- **Recommend that the Parties conduct a review of the adequacy of the Agreement, given the evolving state of basin governance and the need for the Agreement and its institutions, to both adapt to and influence that evolution.**

The board further noted that any "decision as to whether the Agreement needs to be modified should not be predetermined, but should be an objective outcome of the review process."

The board notes that, since its advice four years ago, although a review of the Agreement was initiated through the Parties' Binational Executive Committee, that review was terminated in early 2000 and that no updating of the Agreement has taken place since 1987. The board's review of Annex 1 of the Agreement, discussed elsewhere in this chapter, clearly points out the need to revise that annex, and reviews of other components of the Agreement would likely lead to similar conclusions. The board's advice provided in 1997 remains valid today.

The board reiterates its previous recommendation the IJC that they encourage the Parties to conduct a review of the adequacy of the Agreement.

2.3.3 Nonpoint Sources of Pollution from Land-use Activities

Introduction

Annex 13 of the Agreement "delineates programs and measures for the abatement and reduction of non-point sources of pollution from land-use activities." It calls on the Parties, in conjunction with state and provincial governments, to identify land-based activities contributing to water quality problems described in Remedial Action Plans (RAPs) and Lakewide Management Plans (LaMPs) and to develop and implement watershed management plans. In this section, the board provides advice regarding the mitigation of pollution from nonpoint sources.

Over the past several years, the Parties Implementation Work Group has been studying the role of nonpoint source (NPS) pollution in Great Lakes water quality and the efforts of the Parties to control and prevent that pollution. As part of its 1997-99 Priorities Report, the work group presented the findings of a workshop held to commemorate the 20th anniversary of the final report of the Commission's Pollution from Land Use Activities Reference Group (PLUARG). That report concluded that NPS pollution remains a significant challenge in the Great Lakes basin, particularly in light of the intensification of agricultural practices and the rapid urbanization of many parts of the basin. In its priorities report, the board therefore recommended that the IJC urge the Parties to continue action and vigilance in the control of NPS pollution. In addition, the board emphasized the need for special attention to urbanizing areas.

In this current cycle, the work group continued its investigations into this important area. As part of this effort, it commissioned three reports by senior undergraduate environmental science students at the University of Guelph, Ontario. The first of these reports (Cakmakci et al. 2001) assessed the current state of agricultural NPS pollution control and identified emerging trends and research gaps in that domain. The second report (Fata et al. 2001) made a parallel assessment of urban NPS pollution and its control. The third report (Beyba et al. 2001) compared the pollutant sources, water quality, and management practices of two similar basins, the Grand River in Ontario and the Maumee River in Ohio.

The findings of these studies bore striking similarities, even though their subject material varied widely. The most important of these was the conclusion that nonpoint sources remain a significant source of pollution to the Great Lakes. Although total soil erosion in the United States dropped 42 percent between 1982 and 1997 (Uri and Lewis, 1999),

pollution from land-based activities continues to impose substantial costs, particularly in the Great Lakes basin with its rapid urbanization and intensive water use. The current research reveals a large number of traditional and innovative management practices that have clearly been shown to reduce soil erosion and associated pollutant transport. Technical control of NPS pollution is feasible, practical and cost-effective. The study concluded that the barriers to NPS control are not technical.

Current research also suggests that the principal roots of the problem are not regulatory, although there is certainly room for improvement, particularly in the control of discharges from intensive confined animal feeding operations. In both urban and rural environments, even control programs with the best of intentions will fail if resources are not available for effective enforcement. Numerous studies have demonstrated that effective control of NPS pollution demands site-specific assessment techniques and remedial measures. Because NPS pollution arises over a large land area, its control demands an understanding of the physical, chemical and biological characteristics of the land surface. In some cases, this means tailoring control measures to conditions at the field level within a farm or in a particular residential lot.

It is clearly not feasible to develop environmental management plans at a scale of meters. Yet it is equally clear that generic solutions are unenforceable and not necessarily cost effective. One solution is to prioritize areas and solutions based on hydrology, climate and precipitation patterns, specific pollutants and existing treatment facilities, and concentrate planning and management activities on those areas. Geographic information systems and remote sensing data may be helpful in establishing management priorities and, if linked to predictive computer simulation models, in developing the most effective management strategies.

Some of the literature indicates that public education programs can be helpful in increasing the proportion of landowners that adopt NPS controls, but that the legal language of laws and policies makes the programs inaccessible to many members of the public. It is equally clear, however, that bottom up, landowner-driven strategies have in many cases been more effective than traditional public education approaches. Social marketing strategies in particular do not dictate a preferred approach but, rather, build NPS control programs from the needs and desires of the target audience. Social marketing approaches are based on comprehensive research and evaluation of local environmental, economic, and social conditions – emphasizing once again the need for site-specific solutions.
This need for site-specific approaches may underlie much of the management challenge of NPS pollution. In particular, the current research suggests that control of NPS pollution has been hampered by:

- insufficient persuasive evidence of the effectiveness of best management practices;
- lack of performance standards;
- inadequate financial incentives for clean-up; and
- inadequate institutional arrangements.

The following paragraphs summarize current thinking on each of these topics.

Insufficient Persuasive Evidence of the Effectiveness of Best Management Practices

Consistent with the findings presented in the board's 1997-99 priorities report, the current research underscores the need for much better information on NPS loadings of pollutants with and without best management practices in place. This type of information – exemplified in inventories such as the National Pollutant Release Inventory in Canada and the Toxics Release Inventory in the United States – currently forms the cornerstone of point source pollution control. Yet fundamental information about the quantities of pollutants contributed by individual NPS control practices to receiving waters, the nature and magnitude of associated impacts, and the costs of control (and lack of control) is almost entirely lacking in the NPS domain. Although research is conducted in this area, little seems to find its way into public outreach or extension activities. Furthermore, much of the available information comes from U.S. systems; very little agricultural or urban NPS loading or control information specific to Canada was apparent in the current literature search. In part this may be a function of the Parties' differing communication strategies. Generally speaking, information on NPS pollutants and control strategies is more easily available, in a wider range of formats, in the United States relative to Canada. For example, the (U.S.) National Stormwater Best Management Practice Database provides a comprehensive, user-friendly guide to storm water control. By contrast, Canadian information was much more limited and much more difficult to access.

Recommendation

The SAB recommends the following to the IJC.

- **Recommend that the Parties quantify pollutant loadings to receiving waters by individual nonpoint source control practices; the nature and magnitude of associated impacts; and the costs of control (and lack of control) of nonpoint source pollution.**

A second, related consideration is the almost complete absence of strategies to evaluate the effectiveness of urban and agricultural NPS programs, despite the many millions of dollars that have been spent on them by governments and

private landowners. Methodologies for such assessment, commonly termed program evaluation,, are widely available in the social science literature and indeed are required by many major granting agencies, such as the Canadian International Development Agency and U.S. Agency for International Development. Program evaluation is widely used in government, and many agencies have formal program evaluation offices. Formal program evaluation normally assesses:

- program inputs, including human and financial resources;
- program activities;
- program participants;
- reactions attributable to the program; and
- measurable outcomes, including changes in knowledge, attitudes and skills in addition to biophysical changes, such as pollution reductions.

. . . local ordinances often specify the type of required treatment (e.g. a storm water retention pond) but not the expected level of performance (e.g. expected percent removal of a given pollutant) of that device. There is now considerable evidence indicating that the performance of even the most common urban and agricultural best management practices varies widely depending on age, maintenance history and local conditions.

Without program evaluation, it is difficult for governments and non-government organizations to develop persuasive evidence that any one type of program or best management practice is superior to another. For example, in the Maumee River, as with other Areas of Concern, the purpose of the RAP is to establish strategies to identify and address pollution problems. Although the RAP may coordinate remedial actions, it does not have the authority to impose responsibility for achieving results, nor does it have a means of measuring the success of individual measures. So although the RAP team may recommend NPS control strategies, they cannot guarantee that those strategies will be implemented, nor can they promise or measure any particular level of performance. Landowners within the RAP area may therefore be reluctant to risk significant expenditure on control measures whose performance is not proven, and progress on NPS controls may be slowed.

In contrast, most point source controls are regularly and closely scrutinized to ensure cost-effectiveness, in part because of the need for accountability to owners and directors (or to the public, in the case of a public utility) for each expenditure. It is therefore often possible for the discharger to state that an expenditure of X dollars will result in an estimated Y percent pollutant reduction. This information is powerful and persuasive evidence that proposed expenditures will have the desired environmental impact.

Recommendation

The SAB recommends the following to the IJC.

- **Recommend that the Parties adopt systematic methods to evaluate nonpoint source pollution control programs.**

Lack of Performance Standards

A second major obstacle to implementation of NPS controls is the absence of performance targets for the land surface and for individual management practices. Although available, ambient water quality guidelines are of little help, especially in view of the dearth of loading information described above, in establishing targets for nutrient concentrations, metals, pesticides, solvents, microorganisms and similar constituents on the land or in treated effluent from best management practices. Some jurisdictions, for instance Pennsylvania, have attempted to set regulatory performance criteria for nutrient management practices (see, for example, Beegle et al. 2000). However such approaches are rare.

Instead, local ordinances often specify the type of required treatment (e.g. a storm water retention pond) but not the expected level of performance (e.g. expected percent removal of a given pollutant) of that device. There is now considerable evidence indicating that the performance of even the most common urban and agricultural best management practices varies widely depending on age, maintenance history and local conditions. Furthermore, it is increasingly evident that, although the percentage of impervious land surface is a good predictor of urban water quality impairment, planning ordinances rarely if ever impose restrictions on this factor. In the absence of such performance benchmarks, it is diff ·ult for enforcement staff to assess the adequacy of existing management practices in urban or rural settings.

Landowners may be aware that NPS pollution should be controlled and that certain practices are desirable, but they may be reluctant to proceed with implementation because of uncertainty as to the necessary scope and cost of work. Program evaluation would provide evidence of the cost-effectiveness of preferred management approaches, and thus remove a barrier to implementation of NPS controls.

Recommendation

The SAB recommends the following to the IJC.

- **Recommend that the Parties develop performance standards for nonpoint source pollution control technologies, including standards for the land surface.**

Economic Considerations

Many studies have demonstrated that economic considerations are critical in the implementation of NPS controls. The current research reveals a lack of detailed information on farm- or lot-level economic forces, and the factors that encourage, or discourage, the landowner from adopting best management practices. It is, however, apparent that, in many cases, existing regulatory structures in fact work to separate landowners from the true costs of their behaviour. For example, existing Right-to -Farm legislation in both countries exempts agricultural operations from most environmental regulations.

Inappropriate land management techniques can create significant costs for downstream users, but these costs are largely invisible to the landowner from whose lands pollution or eroded sediment arises. For example, soil lost from agricultural lands is the major source of suspended sediment pollution in the Maumee River. These sediments must be dredged yearly and confined as contaminated soil by the U.S. Army Corps of Engineers, at an estimated annual cost of $3 million (U.S.). Currently, these funds come from public coffers, but other approaches may be necessary. In particular, there is considerable potential for application of economic instruments in the control of NPS pollution. At present, such instruments are limited to grants and subsidies, particularly in the agricultural sector. Additional opportunities may exist, not all of which have implications for trade agreements. Examples might include compensated conservation easements (in which a farmer grants limited use or retirement of land in exchange for compensation), performance bonds (that can be repaid on demonstration of satisfactory performance), and grants and subsidies for land stewardship and habitat restoration. Such instruments are already common throughout the Organization for Economic Cooperation and Development countries (OECD 1999), including Canada and the United States.

Site-specific measures such as so-called prescription agriculture (in which global positioning systems are used in combination with frequent soil testing to determine optimal fertilizer application rates within a field) offer a means of minimizing fertilizer use and associated costs, and therefore implicitly provide financial incentives for NPS control. Prescription agriculture technology is potentially costly, however, and may require financial subsidies in addition to the savings realized in fertilizer use.

Recommendation

The SAB recommends the following to the IJC.

- **Recommend that the Parties extend the use of economic incentives for the control of pollution from nonpoint sources.**

A more subtle economic consideration is the under pricing of water throughout most of the Great Lakes basin. The literature suggests that many jurisdictions set water prices at approximately two-thirds to three-quarters of the true cost of delivering water and sewerage services. Some estimates place current prices at half their real cost. This situation differs markedly from other regions in the world, which have much higher wat prices and much lower per capita use. In terms of NPS controls, the implications of excessive water use and low water costs are clear — more water use means faster deterioration of water infrastructure, higher energy costs and greater potential for erosion and pollutant transport.

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Also, no jurisdiction attaches a price to the water itself, whether surface or ground water, even in situations where local scarcity of that water proves that it is a limited and valuable resource. Moreover, at a time when residents of the Great Lakes basin worry that other regions may propose exports of Great Lakes water, that water is still available at zero price as if basin waters were an inexhaustible and unlimited resource.

Recommendation

The SAB recommends the following to the IJC.

- **Recommend that the Parties adopt full-cost pricing of water and sewerage services, incorporating a scarcity value of the water and including provisions for infrastructure maintenance, upgrading and replacement.**

Inadequate Institutional Arrangements

Possibly the most dramatic and consistent finding arising from the current research is that current institutional arrangements may in themselves create significant obstacles to the control of NPS pollution. Problems with institutional arrangements stem from three sources:

- lack of communication and coordination among levels of government in the control of natural resource stewardship, land use planning and control of NPS pollution;
- lack of integration of planning policies with environmental protection policies; and

- lack of collaborative multi-stakeholder approaches to planning, management and research.

To a large extent, current institutional arrangements derive from the government structures and attitudes of the 1970s and 1980s, which were generally based on political boundaries, divided along environmental media lines, and emphasized information dissemination over collaboration.

It is increasingly clear that such arrangements fail to foster the communication necessary for control of NPS pollution. For example, although NPS controls are most effective if based on site-specific assessments, there is also a need for regional coordination of land use planning, including NPS management practices. Most jurisdictions have found this difficult. For example, the Maumee River watershed crosses the border between Ohio and Indiana, thus dividing responsibility for water quality between the two jurisdictions. Although the RAP structure provides a framework for coordination of activities in the area, the Maumee Area of Concern does not include the full watershed area, so upstream pollution sources are excluded from RAP deliberations.

By contrast, water management decisions in the Grand River basin are overseen by a single agency, the Grand River Conservation Authority (GRCA). This arrangement is facilitated by the fact that the entire Grand River watershed falls within the province of Ontario. GRCA has spent 25 years developing close working relationships with basin municipalities, all of whom are represented on its technical committees, and include federal and provincial resource management agencies, local non-governmental organizations and the public. Through this framework, GRCA has created an exemplary watershed-based partnership for management of the river basin, and was recently recognized with the 2000 Theiss River Prize as the best water management agency in the world. Among its other achievements, GRCA has succeeded in establishing a sense of team and shared vision within the watershed, which finds practical expression in collaborative research and funding of major planning and management initiatives.

The current research supports the notion that water management, including NPS control, is best conducted on a watershed basis. Although the RAP and LaMP programs are intended to be community based, in practice RAP public advisory committees are often separated from the technical work of the RAP, and may in any case be disproportionately small relative to agency representation. The comparison of the Grand and Maumee management systems conducted in the current research suggests that the successful programs in the Grand River watershed are not initiated by a government body, but rather by citizen groups – in other words, bottom up rather than top down.

GRCA's technical committees have responsibility for point and nonpoint source pollution abatement and for maintaining the river's beneficial uses. Most have membership drawn from across stakeholder groups, who jointly and collaboratively analyze basin data, propose and evaluate remedial actions, oversee monitoring and communicate results to the community. The structure of the Maumee RAP is also effective for identifying problems and initiating the necessary programs, but is less effective in terms of ongoing adaptive management, monitoring and follow-up, perhaps because it lacks the basin-wide endorsement present in GRCA.

The watershed management structure employed in the Grand River also addresses the problem of linkage between the land use planning function and environmental protection. In most jurisdictions, including Ontario, these are separate systems and coordination between them is often weak or lacking. In Ontario, the Planning Act provides for local decision making with provincial oversight but, in practice, oversight occurs only at the level of a dispute resolution tribunal, the Ontario Municipal Board. Legislative reforms proposed by the Sewell Commission in the early 1990s (Sewell et al. 1993) would have introduced formal linkages between the Planning Act and environmental legislation. Those reforms were, however, overturned when the current Conservative government of Premier Mike Harris took office in 1995.

GRCA's collaborative watershed management structure successfully integrates land use planning and environmental management at both local and regional scales. Through its committee structure, individual municipalities and private citizens participate in basin-wide planning and management discussions. A basin-wide hydrologic/water quality model, the Grand River Simulation Model, provides a means of evaluating alternative management strategies, and serves as the basis for discussions about regional priorities. While individuals represent local interests and conditions, regional coordination is provided through round-table discussions. The committee structure, which is based around standing committees and long-term membership, also provides an informal forum for exchange of technical information and advice.

Elsewhere in the world, notably in Australia, innovative institutional arrangements now underlie water management on a watershed basis. Most models incorporate a single lead agency, often at arm's length from, but with participation by, regulatory agencies. Like GRCA, their role is to provide basin-wide oversight of planning, resource management and extraction, pollution prevention and abatement activities, and related matters. Often, water allocation is overseen by the watershed agency, which is also responsible for designating responsibilities, timetables and costs among basin stakeholders. Other key responsibilities include monitoring, often involving a substantial volunteer component coordinated

with community representatives, schools and retirees, and communications regarding watershed quality and activities. Examples of innovative management institutions include the Great Artesian Basin Consultative Council, Lake Eyre Basin Coordination Group, Murray-Darling Basin Commission (all Australian) and the California State Water Resources Control Board's system of regional, but not watershed-based quality control boards.

Recommendation

The SAB recommends the following to the IJC.

- **Recommend that the Parties review current institutional arrangements for water and watershed management, and explore the feasibility of collaborative, multi-stakeholder regional or watershed-based institutional structures.**

The preceding discussion has focused on NPS pollution at the local and regional scales. However, the NPS issue is national and international in scale, and actions at the local and regional levels cannot be taken in isolation of these broader dimensions. The dictum to "think globally, but act locally" clearly pertains.

As noted in the introduction to this NPS discussion, the board had previously concluded that NPS pollution remains a significant challenge in the Great Lakes basin. The PLUARG study was completed a quarter century ago, but we, as a society, are only now beginning to appreciate the depth and breadth of its findings, in light of the rapidly changing agricultural and urban land-use patterns and practices. The PLUARG study was timely in the 1970s, as well as ahead of its time. Perhaps we should each read or re-read the PLUARG report and its substantial supporting documentation. Annex 13 of the Agreement remains relevant and, indeed, control and mitigation of NPS pollution is key to restoration and protection of our Great Lakes.

2.3.4 Evaluation of SOLEC Indicators Relative to the GLWQA

For more than a decade, there has been significant efforts by the Parties and the IJC to develop indicators in relation to the Great Lakes Water Quality Agreement, and it is, perhaps, appropriate at this time to reflect on the purpose of indicators and to evaluate whether these efforts are producing the needed results. In 1996, the IJC published a report titled *Indicators to Evaluate Progress under the Great Lakes Water Quality Agreement* (International Joint Commission 1996). The definition of an indicator was that it "provides a clue to a matter of larger significance or makes perceptible a trend or phenomenon that is not immediately detectable." This definition accords with those used internationally in relation to indicator organisms as "an organism whose characteristics are used as an index of attributes too difficult, inconvenient, or expensive to measure for other species or environmental conditions of interest" (Landres et al. 1988, cited in Ewins et al. 2001). All measurements are not necessarily indicators though some measurements could be used as indicators. For a measurement to become an indicator it must fulfil the following circumstances and criteria.

- There must be a trend or phenomenon that is not immediately detectable.
- There must be a matter of larger significance for which the index provides a clue.
- The measurement must be able to be transformed into a reliable index.

Though indicators are not mentioned in the preamble or in the articles to the Great Lakes Water Quality Agreement, there are several references in the annexes. There are, however, throughout the preamble and the articles, phenomena and matters of a larger significance that are not immediately detectable and for which indicators are required to provide a clue. For example, the Parties concluded in the preamble that "the best means to preserve the aquatic ecosystem and achieve water quality throughout the Great Lakes System is by adopting common objectives, developing and implementing cooperative programs and other measures . . ." Both the preserving of the aquatic ecosystem and the achievement of water quality throughout the Great Lakes system are matters of larger significance and phenomena that are not immediately detectable. For the Parties to report on trends in progress in the attainment of these matters of larger significance, there has been a need, since the signing of the original agreement in 1972, to select indicators and to implement long-term programs to measure their status.

The 1987 Protocol to the Agreement added a supplement to Annex 1 that provides for the establishment of lake ecosystem objectives and designated two species, the lake trout (*Salvelinus namaycush*) and *Pontoporeia hoyi*, (now identified as *Diporeia hoyi*), as indicators of oligotrophic conditions for Lake Superior. Since then, other lake ecosystem objectives have not been added by the Parties, although the SAB has recommended several species for adoption (IJC 1991), including the bald eagle *(Haliaeetus leucocephalus)*, double crested cormorant *(Phalacrocorax auritus)*, mink *(Mustela vison)* and otter *(Lutra canadensis)*. The SAB also recommended that the lake trout objective be further developed to measure exposure to persistent toxic substances by determining the incidence of embryo mortality, fry survival and developmental anomalies in samples of fish eggs (IJC 1991).

SOLEC is one of several reporting mechanisms available to the Parties under the Agreement, which has the potential to be

particularly important as a basis for future reporting on the state of the lakes through the use of indicators. The SOLEC process, generally, also provides an excellent opportunity for Great Lakes scientific and policy communities to consult binationally and to achieve consensus on critical aspects of Agreement implementation. The adoption of a suite of 80 indicators in 1999, based on SOLEC categories of open and nearshore waters, coastal wetlands, nearshore terrestrial, human health, land use, societal and unbounded categories, represented a major transition from ad hoc reporting efforts of the past to a unified reporting method for the future. Yet despite these attributes, SOLEC reporting does not fully satisfy the reporting responsibilities of the Parties under the Agreement, (Environment Canada and U.S. EPA, 2000) and therefore it remains insufficient as a sole basis for evaluating progress under the Agreement by the IJC. Recent IJC efforts of the IETF (Indicators for Evaluation Task Force) and the IITF (Indicators Implementation Task Force) proposed an evaluative framework based on desired outcomes, such as fishability, drinkability and swimmibility (IJC 1996; 2000) and the IITF concluded that continued involvement of the IJC is necessary over the next decade in order to further develop and apply indicators that measure Agreement progress.

In order to assess the suitability of current SOLEC indicators for IJC evaluative purposes, the Work Group on Ecosystem Health received assistance from four graduate students (John Heatley, Sandra Knuteson, Amy Roe, Rick Sherrard) at Clemson University, who undertook research during spring 2000 to determine the extent to which the suite of 80 indicators fulfilled reporting requirements under the Agreement.

The SAB developed a set of criteria for judging the suitability of candidate organisms to serve as indicators of ecosystem quality (IJC 1985). These criteria were to:

- have a broad distribution in the system;
- be easily collected and measured in terms of biomass;
- be indigenous and maintain itself through natural reproduction;
- interact directly with many components of its ecosystem;
- have available historical, preferably quantified information pertaining to its abundance;
- have well documented and quantified niche dimensions expressed in terms of metabolic and behaviourial responses;
- exhibit a gradual response to a variety of human induced stresses;
- serve as a diagnostic tool for specific stresses of many sorts;
- respond to stresses in a manner that is both identifiable and quantifiable;
- be a suitable species for laboratory investigations;
- be generally recognized as important to humans; and
- serve to indicate aspects of ecosystem quality other than those represented by presently accepted parameters.

The graduate students developed a method of ranking each of the 80 SOLEC indicators based upon a set of 12 questions, 11 of which were related directly to the SAB criteria and a 12th on the merit of the indicator and its ability to adequately assess the ecosystem (Table 1). A score of one to five points was assigned to each of the 11 questions related to Ecosystem Health and up to 10 points were assigned for the question on merit, based on the current state of development and future potential of development for the indicator. Each student independently ranked each of the indicators, then a group consensus was reached to assign a final score to each indicator.

Based on these criteria and the indicator information provided in recent SOLEC reports (Environment Canada and U.S. EPA, 1999; 2000), SOLEC indicators classified as excellent, good and moderate, if fully developed, were considered sufficient for meeting the need for ecosystem indicators under the Agreement.

Final scores were assigned to each indicator and were ranked as either excellent (51-70 points), good (40-50 points), moderate (30-39 points) or poor (less than 30 points) (Table 2). Excellent indicators are deemed to adequately represent ecosystem health and all but one were ready to be used in the field. Good and moderate indicators are meritorious, but need more information to establish endpoints before they are ready for use. Indicators ranked as poor were not viewed as adequate to represent ecosystem health and/or lacked merit as an indicator, and did not receive further consideration by the researchers. Ten of the indicators received a classification of excellent. Seventeen of the indicators received a classification of good. Twenty-one of the indicators received a classification of moderate. The other 32 indicators were classified as poor. None of the SOLEC indicators related to its categories of Land Use or Societal indicators were developed enough to be useful and were all classified as poor.

Table 1 SOLEC Evaluative Framework

Developed by Clemson University Researchers

Criteria Group	Criterion	Question(s) to be asked
Specificity to Toxic Substances	Gradual Response	Does it give a gradual response to different induced stresses (dose/ response relationship)?
	Diagnostic Tool	Can it serve as a diagnostic tool specific for many different stresses?
	Quantification	Is the response identifiable and quantifiable?
Placement	Great Lakes Basin Distribution	Is it basin wide, whole lake, limited area (AOC specific)?
	Indigenous	Is it indigenous to the Great Lakes basin with a naturally reproducing population?
	Ecosystem Interactions	Are there key interactions with components of the ecosystems, for example, keystone species?
	Specific Niche	Does it have a specific niche that can be expressed in metabolic and behavioural response terms?
Ease and Cost in Measurement	Ease of Collection	Are there standard methods? Is it quick and easy, cost efficient, taking few resources?
	Historical Records	Are there previous data to study historical trends, current abundance?
	Suitability for Lab studies	Will the indicators be suitable for lab studies?
Social Relevance / Public Perception	Social Relevance	Is it important to public perception?
Future Relevance	Merit	Will it adequately assess the ecosystem?

A second review of the SOLEC indicators and their applicability to IJC objectives, desired outcomes and the annexes of the Great Lakes Water Quality Agreement was included as Appendix 2 in the SOLEC 2000 Draft for Discussion. This review of applicability to IJC related priorities only determined if any applicability to the IJC priority was met by the indicator, and not the adequacy of the indicator to actually achieve these objectives. A number of gaps were identified regarding IJC priorities. SOLEC indicators were not identified for the following IJC priorities: Great Lakes Water Quality Agreement, annexes 4 through 10, and 16; the desired outcome of economic viability; and the beneficial use impairments of tainting of fish and wildlife, beach closings, and agricultural and industrial costs. SOLEC indicators did not adequately cover the following IJC priorities: desired outcomes for dredging, swimability/drinkability and excess phosphorous); and the beneficial use impairments of dredging, fish and wildlife consumption, tumors, drinking water and aesthetics. No attempt has been made by SOLEC to evaluate the adequacy of the SOLEC indicators relevant to any of the IJC priorities evaluated, such as RAPs, LaMPs, the Great Lakes Water Quality Agreement, desired outcomes or IJC objectives. Therefore, the needs of the IJC and the responsibility of the Parties for reporting under the Agreement have not been evaluated for the SOLEC indicators.

Recommendations

The SAB recommends the following to the IJC.

- **Evaluate the utility of SOLEC indicators to fulfill the reporting requirements under the Great Lakes Water Quality Agreement.**
- **Increase the IJC's emphasis on its role to assess the state of the lakes and evaluate progress under the Great Lakes Water Quality Agreement, now that a framework for indicators and reporting has been developed.**

Table 2 **Ranking of Indicators Deemed as Excellent, Good and Moderate in Fulfilling Reporting Requirements under the Agreement**

SOLEC No.	SOLEC Indicator Name	Ranking
EXCELLENT		
4179	Geographic patterns and trends in human disease incidence	70
4503	Deformities/eroded finds/lesions/tumors (DELT) in fish	58
8135	Contaminants affecting productivity of bald eagles	57
101	Deformities/eroded fins/lesions/tumors (DELT) in fish	56
115	Contaminants in colonial nesting waterbirds	55
93	Lake trout and scud	54
113	Contaminants in recreational fish	53
9000	Acid rain	52
111	Phosphorous concentrations and loadings	51
8	Salmon and trout	51
GOOD		
17	Preyfish populations	50
4860	Nitrates and total phosphorous into coastal wetlands	49
114	Contaminants in young-of-the-year spottail shiners	47
9	Walleye and *Hexagenia*	47
4176	Air quality	46
8150	Breeding bird diversity and abundance	46
4175	Drinking water quality	45
109	Phytoplankton populations	44
4083	Chemical contaminants in fish tissue	43
72	Fish entrainment	43
8134	Nearshore plant and wildlife problem species	42
8147	Contaminants affecting the American otter	42
4178	Radionuclides	42
4501	Coastal wetland invertebrate community health	42
4502	Coastal wetland fish community health	42
4088	Chemical contaminant intake from air, water, soil and food	41
4506	Contaminants in snapping turtle eggs	40
MODERATE		
4861	Water level fluctuations	39
117	Atmospheric deposition of toxic chemicals	38
9001	Atmospheric visibility; prevention of significant deterioration	38
7059	Wastewater pollutant loading	38
4081	Fecal pollution levels of nearshore recreational waters	38
4177	Chemical contaminants in human tissue	38
116	Zooplankton populations as indicators of ecosystem health	38
8161	Threatened species	38
118	Toxic chemical concentrations in offshore waters	36
6	Aquatic habitat	36
120	Contaminant exchanges between air to water, and water to sediment	35
4513	Presence, abundance and expansion of invasive plants	35
4510	Coastal wetland area by type	33
119	Concentrations of contaminants in sediment cores	32
4507	Wetland-dependent bird diversity and abundance	32
18	Sea lamprey	31
4511	Gain in restored coastal wetland area by type	31
8137	Nearshore species diversity and stability	31
104	Benthos diversity and abundance	31
4504	Amphibian diversity and abundance	30
4857	Global warming; first emergence of water lilies in coastal wetlands	30

2.3.5 Remedial Action Plan Assessment: Site Visits to the Niagara River and St. Lawrence Areas of Concern

The IJC adopted a status review process for AOCs in 1996, and since that time, three reviews have been completed (IJC 1997a; 1999a,b) and two are currently underway. The SAB has assisted the Commission with the scientific aspects of its reviews and by conducted site visits, holding public meetings and providing advice to the Commission. During the 1999-2001 biennial cycle, the board met in the Niagara River and St. Lawrence Areas of Concern.

Niagara River

The SAB meeting in Niagara Falls, New York was held on November 29-30, 2000, and comprised technical presentations from representatives of the government agencies cooperating under the Niagara River Toxics Management Plan, a tour of the hazardous waste sites on the U.S. side and a public meeting involving invited scientific presentations and interested citizens. The meeting was held in association with the U.S. EPA and New York Department of Environmental Conservation open house for the public and media on remediation of U.S. Niagara River hazardous waste sites. The following comments and conclusions were reached by the board and submitted to the Commission.

1. The Niagara River Area of Concern was designated primarily on the basis of concerns about the input of toxic chemicals to the Niagara River, particularly related to the operation of hazardous waste sites on the U.S. side. Chemical manufacturing involving chlorine started in the 1890s and wastes have been released to the Niagara River and deposited in chemical land fill sites throughout the 20th century. The toxicological situation became particularly acute by the 1940s with subsequent extirpations of fish and wildlife species. These concerns became extremely serious with the realization that chemicals, such as PCBs, Mirex and dioxins from the Niagara region can not only influence all of Lake Ontario and the St. Lawrence River, but can also impinge on the Gulf of St. Lawrence and the Atlantic Ocean.

2. While very serious efforts are underway at each individual waste site to contain movement of chemicals from the sites, the larger reality of the immense geographical and temporal scale of the problem needs to be recognized and acknowledged. For example, approximately 80,000 tons of waste, some of which is hazardous material, s contained at the Hyde Park dump. By pumping and treating water infiltrating the site, about eight pounds of chemicals are removed and treated daily. Nevertheless, U.S. EPA, NYDEC and industry should be commended for their management efforts in containing toxic wastes onsite.

For example, approximately 80,000 tons of waste, some of which is hazardous material, is contained at the Hyde Park dump. By pumping and treating water infiltrating the site, about eight pounds of chemicals are removed and treated daily. Nevertheless, U.S. EPA, NYDEC and industry should be commended for their management efforts in containing toxic wastes onsite.

3. The monitoring and surveillance programs under the Niagara River Toxics Management Plan are models for binational cooperation and success. The results of remedial efforts and waste containment activities are reflected in dramatic reductions in ambient levels of pollutants both in the river and in biota. The effectiveness of monitoring programs strongly support the value of applying this approach for the other connecting channels.

4. The containment of the wastes, the reduction of contaminant inputs to the river, and the relocation of homes and citizens has resulted in a noticeable lack of public outrage and concern, in contrast to the early days of citizen activism in the region. While these actions appear to be have been successful, a comment at the board's public meeting reminded officials that such measures do not comprise remediation or cleanup, and commit government and industry to long term, high cost solutions for this legacy, in perpetuity. There was some apprehension expressed whether this commitment would be sustained in the face of high cumulative costs of containment and the absence of immediately affected citizens to demand action.

5. The importance of dense non aqueous phase liquids (DNAPL) in fractured rock aquifers is well understood scientifically, however this knowledge is only beginning to be applied in terms of operational practices. Since it is difficult to locate the DNAPL in fractures and even more difficult to access it, pump and treat technology is not very effective for removal. The primary intention of pump and treat technology is to reverse the hydraulic gradient at a contaminated site, however, small amounts of contaminants DNAPL will be removed with the water and is treated before it can be discharged. Over

the long term, DNAPL could become increasingly significant as an ongoing source requiring treatment as more soluble wastes within the site are removed with groundwater. Also, given the limited access of the groundwater to the DNAPL in fractures of rock, the effectiveness of maintaining an inward hydraulic gradient on DNAPL movement is difficult to predict. In addition, as time goes on and the more accessible DNAPL sources are reduced, concentrations in the water will be reduced and more water will have to be pumped to remove a given amount of contaminants. There appears to be very limited applied research into alternatives to pump and treat technologies in the Niagara region involving local hydrogeological expertise at nearby universities or involving institutions such as the U.S. Geological Survey. The Niagara region offers an opportunity to better develop the science and engineering of DNAPL treatment and this improved understanding is needed to address the future challenges of site remediation.

6. Because of the severity of the problems, the Parties chose to manage toxic substance problems using the respective regulatory frameworks in each country and binationally under the auspices of the Niagara River Toxics Management Plan (NRTMP). The NRTMP comprises the Niagara Declaration of Intent, a four party agreement that provides for an annually updated workplan aimed at reducing concentrations of chemicals in the river. While the NRTMP is essentially a subactivity within the Niagara River RAP, RAP efforts in both countries have played a limited or marginal role in addressing problems of toxic substances. For example, in Canada, most RAP concerns are related to the Welland River. At best, the development of the RAP has poor binational coordination, is not managed binationally using an ecosystem approach, and does not appear to be a high priority of the senior governments. There is a need to have more binational linkages between the NRTMP, RAPs and Lake Ontario LaMP. It could also be warranted, to encompass the research and monitoring activities occurring in the St. Lawrence River and the Gulf of St. Lawrence, with reference to previous comments numbers 1 and 2.

7. For the short term, the crisis of hazardous waste management appears to be manageable through containment at individual priority waste sites. But issues related to other sources to the Niagara River, including, for example, upstream inputs, non priority waste sites, contaminated sediments, and other nonpoint sources, continue to have an impact on beneficial uses and will necessitate ongoing fish consumption advisories for the foreseeable future. For example, there are more advisories, and the advisories are more restrictive in the Lower Niagara River than in the Upper Niagara River. By 2003, current approaches related to source track down are scheduled to be completed in terms of the 26 priority sites identified by U.S. EPA. For further reductions, it may become necessary to better account for other sources, sinks and pathways, especially as they relate to Lake Ontario so that best management decisions and measures can be adopted.

8. There is limited flow of information related to the Niagara region, particularly to support a transfer of waste site management technology throughout the Great Lakes basin, and there is a need for an increased role for the Great Lakes National Program Office of U.S. EPA to facilitate greater awareness between the EPA regions and in those AOCs with similar, but admittedly smaller scale problems. The mayor of Niagara Falls highlighted this issue in terms of increasing the profile of the environmental accomplishments in the area and showcasing them as learning experiences for others.

9. The waste management approach through containment has resulted in extensive areas of restricted, grassed, open space that may exist within the town for decades, even centuries. From a land-use perspective, such areas will continue to have a severe economic and social impact on the city as long as they are unusable. Addressing the legal, design and environmental impediments to be overcome in order for these areas to be used for beneficial purposes, such as open public space, in the long term, need to be considered.

St. Lawrence River

In the 1997-1999 Priority report (IJC 2000), the SAB recommended the Commission conduct a status assessment review of progress of the Cornwall/Massena AOC following receipt of the Stage 2 RAPs. The SAB met in Cornwall on May 23-24, 2001 and toured three industrial sites undergoing remediation on the U.S. side. Board comments are as follows.

1. Overall, the board is impressed with the progress being achieved at the three U.S. industrial sites, GM, Reynolds and ALCOA. These efforts are significant and contrast with the lack of any remedial action on the Canadian side of the St. Lawrence AOC.

2. Despite this progress, at the GM site, concerns were expressed at the long delay prior to the removal of the most contaminated material from the site. It appeared, to those board members present, that a step-wise, strategic approach, with priorities based on protecting public health, might have resulted in earlier and more effective action. It is recommended that following validation and discussion of these concerns with the company, the decision-making process used in the GM project should be subject to an independent management review, with a

view to improved accountability and streamlining of the regulatory system.

3. Consideration of the impact and significance of volatilization of PCBs was apparently not required by regulators in determining the remedial measures for the Reynolds site. Volatilization at this site is further increased by the use of an air curtain, an efficient method of stripping PCBs from water, employed to contain the sediments resuspended during the dredging operation. Volatilization of PCBs is known to be important and has been addressed at other AOCs, for example, in the design and implementation of the dredging plan for the Grand Calumet River. It could be quantified through a modeling study using current scientific methods. Such a study would allow decision makers and evaluators to assess the magnitude of releases and consequent risk to public health arising from the open handling of PCB contaminated material against the cost and feasibility of mitigative measures. Without this information, it is open to debate whether the most cost effective results are being achieved under the existing work plan, and the impact to Canada cannot be quantified. The rationale for selection of an air curtain by the company and the U.S. EPA in the dredging project, and the lessons to be learned for future remediation projects should be examined.

4. Current monitoring efforts, particularly biomonitoring, would appear to be insufficient to allow adequate project management and post-evaluative assessment and would benefit from a plan, technical review and public release of the results.

5. The foregoing comments pertain primarily to the capability of governments to carry out their oversight, management and decision-making responsibilities in a manner that applies the best science and technology available to assist them in achieving their environmental goals of remediation. Governments should be encouraged to improve peer-review processes or to use outside human resources when necessary, in order that knowledge and expertise are available that ensures the highest standard of cleanup is prescribed and approved.

2.3.6 The Use of Atmospheric Modeling in Policy Development and Using Models to Develop Air Toxics Reduction Strategies

The capability and utility of atmospheric models as a basis for policy and regulatory decision making toward the further control of emissions of persistent toxic chemicals was addressed through the collaborative efforts of the Delta Institute, the IJC's International Air Quality Advisory Board and the Science Advisory Board at a series of two workshops held in July and November 2000.

The substantive findings and recommendations to the IJC from both events are found under the chapter four of the this report and prepared by the IAQAB.

The first workshop identified the capacities of models as scientific tools to contribute knowledge and understanding of the processes and fate of atmospheric sources of persistent toxic chemicals, particularly in the linkage of proximate and more distant sources to receptor regions, such as the Great Lakes. While the need to further acquaint the policy-making community on the application of models was evident, it was made clear that such physical models would be applied together with other models, such as risk analysis and socio-economic impact assessments in formulating policy.

The second workshop considered the application of various models to a determination of sources and extent of contamination of the Lake Michigan basin by selected persistent toxic substances, with reference to parallel modeling efforts in other parts of the world. A preliminary identification of significant areal emission sources, particularly of PCBs, was offered and recommendations for further source identification, ambient monitoring and modeling activities were also developed. The Delta Institute also tabled a preliminary strategy for reducing air toxics deposition to Lake Michigan based largely on data and information from the Lake Michigan Mass Balance Program of the U.S. Environmental Protection Agency.

The Science Advisory Board concurs with the findings of the IAQAB, and endorses their recommendations (found in Chapter 4) arising from these two activities.

2.4 EMERGING ISSUES IN GREAT LAKES SCIENCE, RESEARCH AND POLICY

2.4.1 Application of a Methodological Framework and a Proposed Process for Agreement Institutions in Addressing Emerging Issues in Great Lakes Science, Research and Policy

Since its last report, several academic and governmental initiatives related to the identification and assessment of emerging issues, and in particular the role of science, have taken place (Munn 1999; Munn et al. 1999; Victor et al. 2000). The improved understanding of phenomenon, such as the geochemical cycling of contaminants, the increased capabilities of monitoring and detection of biological effects of pollutants, and the widespread development and use of sophisticated models at global, regional and local scales, has improved the value and relevancy of forecasts for policy development. The recognition of emerging issues provides an opportunity for policy and decision makers to identify salient topics for further research in areas that may be unproven, not well understood, or related to social and economic trends that are difficult to quantify. More fundamentally, knowledge of emerging issues can result in proactive policies and actions that avoid potential problems before they occur, and is thus linked to the cornerstone of environmental policy and pollution prevention.

In Chapter 1 of the *1997-99 Priorities and Progress under the Great Lakes Water Quality Agreement* (http://www.ijc.org/comm/pr9799.html), the Science Advisory Board's Work Group on Emerging Issues indicated that it intended to apply a more methodological approach to the assessment of emerging issues. It identified the work of the U.S. EPA Science Advisory Board as one approach meriting attention. A current review of best practices commissioned by the Ontario MOE recommended that a modified version of the U.S. EPA methodology be adapted for use by the ministry. In the report, Victor *et al.* noted that there is "no single example of a thoroughly successful emerging issues procedure or process in use by an environmental agency anywhere in the world" (Victor et al. 2000).

In order to apply the U.S. EPA methodology, the SAB work group collaborated with the Emerging Issues Committee of the Council of Great Lakes Research Managers to identify a range of issues based on expert judgement and assessed them using the standard values and criteria weights.

The assessment methodology is a ranking procedure based on five criteria related to impact and one criterion based on probability. The score for each criteria is assigned an initial value within a range of one to five and then the score is adjusted according to an assigned weight. These are: novelty - 10; scope - 7; severity - 10; visibility - 5; timing - 5; and probability - .5. Since probability assesses the likelihood that an issue will need to be addressed, it is an integrative and predictive criterion, highly dependent on the five impact criteria. Probability values were estimated in percentage terms, based on how likely it is that the specific emerging issue will occur. For example, 100 percent probability has an effect equal to the highest rating of a novel issue, one that has never been seen before. The work group found these values and criteria weights to be appropriate to apply the methodology to Great Lakes emerging issues, however, it recognizes that they could also be adjusted to emphasize different attributes, to reflect other priorities, or if one simply disagreed with the original proposed weighting.

With this scheme, an issue with the highest priority is one that is entirely novel, severely affects essentially everyone, is publically visible, apt to be felt soon, and is highly probable to emerge. The first five criteria characterize an issue assuming it develops as foreseen, while the final criterion reflects the extent to which the issue will develop and needs to be addressed within a relevant future time frame.

A methodological approach to the assessment of emerging issues also provides for further analysis of the results. For example, by assessing impact scores against probability scores it is possible to identify four tiers of concern: high impact/high probability - major issues to be addressed immediately; high impact/low probability - surprise issues requiring no regret policies; low impact/high probability - preparation needed for appropriate response; low impact/low probability - not urgent, watch and wait.

In applying this assessment methodology, the work group and the Council of Great Lakes Research Managers identified the following 18 emerging issues.

- **New or Unmonitored Contaminants in Wastewater, Including Pharmaceuticals**

Chemicals specifically listed in the Great Lakes Water Quality Agreement and its appendices constitute only a part of the greater discharge of substances into Great Lakes waters. Little

attention has been given to several, more diverse groups of substances, including pharmaceutical agents and the bio-active ingredients in a wide array of personal care products.

- **Emergence of New Pathogens**

New infectious type agents are referred to as 'emerging pathogens' and are treated as separate issue from emerging contaminants, such as the chemical and pharmaceutical compounds, discussed above. Pathogens in Great Lakes waters that have been identified over the past decade, typically as a result of outbreaks, include *Cryptosporidia*, *Giardia*, *Cyclospora* and *Escherichia coli*. A pathogen that is always of potential concern is cholera, which is ever-present in waters elsewhere in the world and has been shown to be spread by the release of ships' ballast water.

- **Groundwater**

Wise management of water resources in the Great Lakes requires an understanding that groundwater is a large component of the Great Lakes water budget. Decisions that affect the quantity or quality of groundwater discharge to tributary streams and coastal wetlands also affect the quantity and quality of water in the Great Lakes and the health of the Great Lakes ecosystem.

- **Invasive Species**

Currently there are more than 160 nonindigenous species in the Great Lakes, with more discovered each year. Numerous studies have documented the serious environmental and economic consequences associated with alien invasive species becoming established. Many vectors for transporting alien invasive species have been identified, however the discharge of ballast water from ships entering the Great Lakes from other regions of the world is seen to pose the biggest threat.

- **Biotechnology: Engineered Risks of Bioengineered Species**

What are the ecological risks to plants and fish from releasing genetically modified organisms into the Great Lakes basin?

- **Globalization of Trade and Environmental Issues**

The importance of economy and environment linkages and the direct and indirect impacts of increased economic activity on the environment are serious concerns so that competitive advantage does not result in diminished environmental quality. For Great Lakes industry, what are these issues, and what is their potential to impinge on Great lakes water quality?

- **Biodiversity Decline**

This has generally been defined as a global and a regional conservation issue. For the Great Lakes, there is insufficient data available to determine the significance of species loss to the biological integrity of the waters. Once this can be defined, a strategy to restore and protect native species needs to developed.

- **Integrated Monitoring and Observing System**

An automated system based on remote sensing and satellite communication, coupled with models to derive the state of the lakes and trends over time, is needed for the critical pollutants.

- **Nutrient Targets**

Phosphorous continues to be a major source of concern in the Great Lakes, with implications for fisheries and non point management efforts. Are new targets needed under Annex 3, and how should they be derived?

- **Ecological and Socioeconomic Issues of Water Level Changes**

Significant fluctuations of Great Lakes water levels has occurred and will continue in the future. How might these changes affect water quality, both directly and indirectly? Direct effects could include increased concentration of persistent toxic substances, for example, while an indirect effect could include more navigational dredging involving contaminated sediments.

- **Biological Integrity**

What is the scientific definition of biological integrity and what policy actions are necessary to achieve it?

- **Population Growth Impacts on the Great Lakes**

Growth in population and economic activity, along with climate change, may lead to water shortages in some regions of North America. What are the implications for the Great Lakes region? What are the implications for the Great Lakes from the negative impacts of sprawl, increased vehicular use, solid waste management and agribusiness?

- **Improved Resource Evaluation**

Current techniques to value non-monetary benefits to protect and restore natural resources are limited. How can the decision making process better take into account development decisions to protect human and ecosystem health?

- **Climate Change**

Increasing reliability of global circulation models makes it increasingly possible to identify local climate change factors and impacts. What will these be, based on the latest research?

- **Toxics and Toxins**

This topic includes all aspects of biological and chemical pollutants, such as unmeasured or unevaluated chemicals, human health impacts and trends in critical pollutants.

Recent reviews of emerging issue processes in other agencies and internationally identified the need to adopt both a formal procedure and process to benefit from the visionary capabilities of a societies' most innovative and creative members. The work group believes that the current approach is insufficient to meet the needs of the IJC in fulfilling its alerting role in advising the Parties.

- **Air Quality**

What are the implications for the lakes of eventual nuclear power plant closings? What are the implications of ongoing long range sources for RAPs and LaMPs?

- **Synergistic and Additive Effects of Toxic Mixtures**

The Great Lakes Water Quality Agreement delineates research needed to support its goals in Annex 17. Research to develop action levels for contamination that incorporate multi-media exposures and the interactive effects of chemicals was identified as a priority issue for the Parties to the Agreement.

The results provided an overall ranking based on the submission of individual assessments, thus providing a basis for possible consensus or further discussion. Because the exercise tested the veracity of the methodology and there was only a small number of participants involved, the actual ranking of the issues was deemed to be less important than the process used for eliciting them. Therefore, the work group does not intend to apply the results or make recommendations based upon them at this time.

As noted in the SAB's 1997-99 report, a major strength of future research and analysis is to provide a methodological framework to assess information and influence decisions and actions, especially research agendas. The U.S. EPA methodology comprises one approach that demonstrated merit and has potential for use in other exercises of this kind in the future. In applying the methodology however, the importance of a process to ensure involvement of a sufficient number of informed participants was viewed as essential to obtaining robust results. Recent reviews of emerging issue processes in other agencies and internationally identified the need to adopt both a formal procedure and process to benefit from the visionary capabilities of a societies' most innovative and creative members. The work group believes that the current approach is insufficient to meet the needs of the IJC in fulfilling its alerting role in advising the Parties.

Recommendations

Accordingly, the SAB recommends the following to the IJC.

- **Direct a specific group to be responsible for organizing and managing a workshop to identify trends and emerging issues under the Great Lakes Water Quality Agreement at the beginning of each biennial cycle, report on the outcome of their work at the IJC biennial Public Forum, and consider the information when developing work plans for priority activities during each next biennial cycle.**

- **Direct the advisory institutions of the IJC, according to their roles relative to the science, research and policy relevance of an issue, to take a lead role in assessing those issues related to their mandate.**

- **Direct the advisory institutions to provide a regular report on emerging issues to the IJC, as part of their biennial reporting process under the Agreement.**

While the proposed workshop is not envisioned to be large or extensive, it would require some resources on a biennial basis. It is envisioned that the workshop would be attended by invited experts along with board, council and task force members, and would need to focus on at least four major elements in order to provide a comprehensive approach:

- new effects on humans, fish and wildlife related to water quality;
- new chemical agents;
- new sources of pollution; and
- new policy approaches to current problems.

Public interest in emerging issues is also valuable and should be encouraged. Currently the work group maintains a presence through the IJC web site and welcomes public advice through response to its survey questionnaire.

2.4.2 Green Chemistry

In the 1993-95 report from the SAB, the green chemistry approach to less polluting synthesis of chemicals was described. In particular, the ways in which such approaches can minimize waste generation or reduce the toxicity of waste streams were highlighted. Over the last five years there has been development in the scope of green chemistry or cleaner production technologies. Major national or regional awards and research grants for green chemistry are established or proposed in U.S. and Europe. The U.S. Presidential Green Chemistry Challenge is one of the earliest initiatives of this nature (http://www.epa.gov/opptintr/greenchemistry).

Companies that have developed new, less-polluting processes or products are showing that progress can be made using green chemistry approaches and leaders in industry and academia are receiving recognition through such awards.

Equally important, broader principles (see Table 3) and longer-term goals of green chemistry (Collins 2001; Smaglik 2000) have been articulated. These include approaches to more benign reagents and synthetic pathways, but also go further, raising fundamental questions around molecular synthesis and the concepts of 'single product' manufacturing philosophies, with concomitant by-products and impurities. New approaches to industrial design, the next industrial revolution (McDonough and Braungart, 1998), while in their infancy, provide even higher goals for a green chemistry philosophy, separating biological recycling and technical recycling streams and creating new manufacturing challenges.

The U.S. EPA Office of Pollution Prevention is showing leadership in promoting green chemistry and it appears to be gaining ground within industry and academic institutions. In Canada, while there may be specific developments that fit the concept, there is little visibility of a green chemistry icon within industry, academia or government. For example, in Canada, a significant initiative is currently underway to provide increased partnerships with industry to strengthen innovation by strategically assisting and investing in research and development opportunities while at the same time increasing the research capacity of Canadian universities and government laboratories and institutions through a global strategy for Canadian science and technology. More effective coordination of this program with Environment Canada under a green chemistry banner would serve industry, which has to meet environmental and business competitive goals from its own research and also represent a classic environment and economy linkage, with broader societal benefits. What are the prospects for research and development in the Great Lakes basin for green chemistry and what opportunities exist for a binational initiative involving academia, government and industry? What opportunities exist for the Parties to promote green chemistry and encourage collaborative approaches that could link the new frontiers of basic chemistry with the relevant environmental challenges of society and industry, particularly in the Great Lakes region? The board

Table 3 12 Principles of Green Chemistry
(Anastas and Warner, 1998)

1. *Prevention.*	It is better to prevent waste than to treat or clean up waste after it has been created.
2. *Atom Economy.*	Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.
3. *Less Hazardous Chemical Syntheses.*	Wherever practicable, synthetic methods should be designed to use and generate sub stances that possess little or no toxicity to human health and the environment.
4. *Designing Safer Chemicals.*	Chemical products should be designed to effect their desired function while minimizing their toxicity.
5. *Safer Solvents and Auxiliaries.*	The use of auxiliary substances (for example, solvents, separation agents, etc.) should be made unnecessary wherever possible and innocuous when used.
6. *Design for Energy Efficiency.*	Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure.
7. *Use of Renewable Feedstocks.*	A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable.
8. *Reduce Derivatives.*	Unnecessary derivatization (use of blocking groups, protection/ de-protection, temporary modification of physical/chemical processes) should be minimized or avoided if possible, because such steps require additional reagents and can generate waste.
9. *Catalysis.*	Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.
10. *Design for Degradation.*	Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.
11. *Real-time analysis for Pollution Prevention.*	Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.
12. *Inherently Safer Chemistry for Accident Prevention.*	Substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions, and fires.

concludes that a more proactive approach is appropriate, given the potential benefits of new more benign technologies.

Recommendation

Accordingly, the SAB recommends the following to the IJC.

- **Recommend that the Parties promote and coordinate research efforts and visibility of green chemistry priorities within their programs, and on a binational level, promote the innovation and adoption of new technologies in the emerging field of green chemistry to Great Lakes industry.**

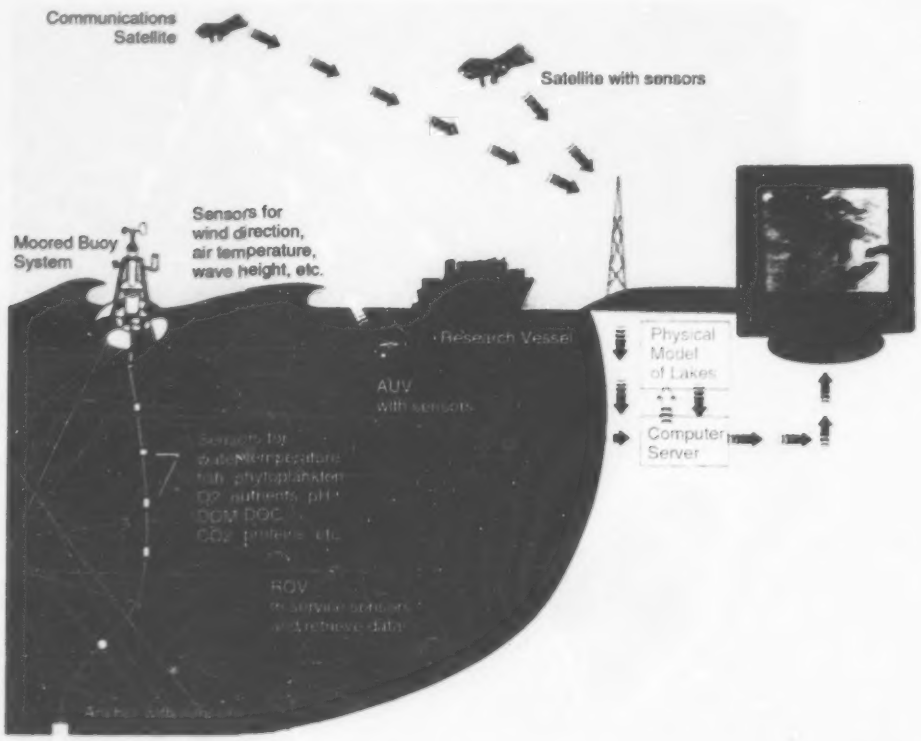
2.4.3 Integrated Observation and Monitoring Network

The need for development of regional coastal observing systems has been recommended by a number of recent reports, including the NOAA Strategic Plan, the National Ocean Partnership Program and the U.S. Coastal-Global Ocean Observing System program.

The Science Advisory Board also suggested in the 1997-99 priorities report that the development of a Coastal Observing System is of fundamental importance for the Great Lakes region. The board argued that the past decade has seen a rapid development of new sensor capabilities, data management, data transmission and data visualization technologies. *In situ* instrumentation is now available with high temporal measurement frequency, as are remote telemetry capabilities, either via hard wire (e.g. fiber optic) or cellular telephone links, and a variety of measurement capabilities, including *in situ* biomonitoring.

The next logical step is to hold a workshop designed to review capabilities and produce a plan for the Great Lakes region. A similar plan has been offered by the oceanic community. The workshop will consist of invited experts from around the world on available and developing *in situ* measuring platforms, sensors, telecommunications, and visualization and modeling needs. The proposed sessions include: User Community Needs, Navigation and Communication, Environmental Sensing and Interpretation, Data Transmission, Management and Visualization, and Status of Stationary and Mobile Underwater Platforms.

The Workshop is scheduled for September 18 - 21, 2001 at the Massachusetts Institute of Technology, Boston, Massachusetts and is cosponsored by MIT and Wisconsin Sea Grants, the IJC, the NOAA Great Lakes Environmental Research Laboratory and the NOAA Office of Atmospheric and Oceanic Research. The anticipated product will be a blueprint for deploying an *in situ* Great Lakes Observation System.



2.5 ACTIVITIES AND MEETINGS OF THE SCIENCE ADVISORY BOARD FOR THE 1999-2001 BIENNIAL CYCLE

116	December 1-2, 1999	Windsor, Ontario
117	February 24-25, 2000	Windsor, Ontario
118	May 4-5, 2000	Windsor, Ontario
119	October 4-5, 2000	Windsor, Ontario The Work Group on Ecosystem Health held a workshop on Methodologies for Community Health Assessment in Areas of Concern.
120	November 29-30, 2000	Niagara Falls, New York Held a Niagara Status Assessment, open house and public forum as well as a tour of a waste facility and some industrial sites.
121	February 22-23, 2001	Windsor, Ontario
	March 21, 2001	The Work Group on Parties Implementation held a workshop on a Review of Annex 1 of the Great Lakes Water Quality Agreement.
122	May 23-24, 2001	Cornwall, Ontario Tour of four industrial sites in Massena, New York.
123	September 13, 2001	Montréal, Québec In association with 2001 biennial Public Forum.

2.6 SCIENCE ADVISORY BOARD AND WORK GROUP MEMBERSHIP 1999-2001

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① Science Advisory Board
② Workgroup on Ecosystem Health
③ Workgroup on Emerging Issues
④ Workgroup on Parties Implementation

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Appendix I. List of Health Outcomes Selected by Health Canada on the Basis That They Might Be Linked To Pollution.
(http://www.hc-sc.gc.ca/ehp/ehd/bch/bioregional/healthdata.htm)

ICD*-9 Category	ICD-9:#	Disease or Condition
		All Causes
Category II		All Malignant Neoplasms
	140-149	Malignant Neoplasm of Lip, Oral Cavity and Pharynx
	146-148	*Malignant Neoplasm of the Pharynx*
	150-159	Malignant Neoplasm of Digestive Organs and Peritoneum
	150	*Malignant Neoplasm of Oesophagus*
	151	*Malignant Neoplasm of Stomach*
	153-154	*Malignant Neoplasm of Colon and Rectum*
	155	*Malignant Neoplasm of Liver and Intrahepatic Bile Ducts*
	156	*Malignant Neoplasm of Gallbladder and Extrahepatic Bile Ducts*
	157	*Malignant Neoplasm of the Pancreas*
	160-165	Malignant Neoplasm of Respiratory and Intrathoracic Organs
	162	*Malignant Neoplasm of the Trachea, Bronchus and Lung*
	170-175	Malignant Neoplasm of Bone, Connective Tissue, Skin and Breast
	172	*Malignant Melanoma of Skin*
	174	*Malignant Neoplasm of Female Breast*
	179-189	Malignant Neoplasm of Genitourinary Organs
	183	*Malignant Neoplasm of Ovary and Other Uterine Adnexa*
	185	*Malignant Neoplasm of the Prostate*
	186	*Malignant Neoplasm of Testis*
	188	*Malignant Neoplasm of the Bladder*
	189	*Malignant Neoplasm of Kidney, Other and Unspecified Urinary Organs*
	190-199	Malignant Neoplasm of Other and Unspecified Sites
	193	*Malignant Neoplasm of Thyroid Gland*
	200-208	Malignant Neoplasm of Lymphatic and Haematopoietic Tissue
	200-202	*Non-Hodgkin's Lymphoma*
	201	*Hodgkin's Disease*
	204-208	*Leukaemia*
Category III	240-246	Disorders of Thyroid Gland
	250-259	Diseases of Other Endocrine Glands
	250	*Diabetes Mellitus*
	255	*Ovarian Dysfunction*
	257	*Testicular Dysfunction*
	270-279	Other Metabolic Disorders and Immunity Disorders
Category IV	280-289	Diseases of Blood and Blood-Forming Organs
Category VI	330-337	Hereditary and Degenerative Diseases of the Central Nervous System
	332	*Parkinson's Disease*
	340-349	Other Disorders of the Central Nervous System
	340	*Multiple Sclerosis*
	343	*Infantile Cerebral Palsy*
	350-359	Disorders of the Peripheral Nervous System
	359	*Muscular Dystrophies and Other Myopathies*
	360-379	Disorders of the Eye and Adnexa
	369	*Blindness and Low Vision*
	380-389	Diseases of the Ear and Mastoid Process
Category VII	401-405	Hypertensive Disease
	410-414	Ischemic Heart Disease
	415-417	Diseases of Pulmonary Circulation
	420-429	Other Forms of Heart Disease
	440-448	Diseases of Arteries, Arterioles and Capillaries
	440	*Atherosclerosis*

Category VIII	460-466	Acute Respiratory Infections
	470-478	Other Diseases of the Upper Respiratory Tract
	470-487	Pneumonia and Influenza
	490-496	Chronic Obstructive Pulmonary Disease and Allied Conditions
	491	*Chronic Bronchitis*
	492	*Emphysema*
	493	*Asthma*
	500-537	Pneumoconiosis and Other Lung Diseases due to External Agents
Category IX	530-537	Diseases of Oesophagus, Stomach and Duodenum
	555-558	Noninfective Enteritis and Colitis
	560-569	Other Diseases of Intestines and Peritoneum
	570-579	Other Diseases of Digestive System
Category X	580-589	Nephritis, Nephrotic Syndrome and Nephrosis
	590-599	Other Diseases of Urinary System
	600-608	Diseases of Male Genital Organs
	606	*Infertility, Male*
	610-611	Disorders of the Breast
	617-629	Other Disorders of Female Genital Tract
	617	*Endometriosis*
	628	*Infertility Female*
Category XI	630-639	Pregnancy with Abortive Outcome
	634	*Spontaneous Abortion*
	640-648	Complications mainly related to Pregnancy
	642	*Hypertension Complicating Pregnancy, Childbirth and the Puerperium*
	644	*Early of Threatened Labour*
	680-686	Infections of Skin and Subcutaneous Tissue
	690-698	Other Inflammatory Conditions of Skin and Subcutaneous Tissue
	700-709	Other Diseases of Skin and Subcutaneous Tissue
Category XII	710-719	Arthropathies and Related Disorders
	720-724	Dorsopathies
	725-729	Rheumatism, excluding the Back
	730-739	Osteopathies, Chondropathies and Acquired Musculoskeletal Deformities
Category XII		All Anomalies
	740.0-742.9	Central Nervous System Anomalies
	740.0-740.2	*Anencephalus and Similar Anomalies*
	741.0-741.9	*Spina Bifida*
	742.1-742.2	*Microcephalus and Brain Reduction*
	742.3	*Congenital Hydrocephalus*
	743.0-743.9	Eye Anomalies
	745.0-746.9	Congenital Heart Defects
	745.4	*Ventricular Septal Defect*
	745.5	*Atrial Septal Defect*
	747.1-747.9	Circulatory System Anomalies
	747.3	*Pulmonary Artery Anomalies*
	748.0-748.9	Respiratory System Anomalies
	749.0-749.2	Cleft Lip and/or Palate
	750.1-751.9	Digestive System Anomalies
	752.6	*Hypospadias, Epispadias*
	753.0-753.9	Urinary System Anomalies
	753	*Renal Agenesis and Dysgenesis*
	754.5-754.7	Clubfoot
	755.0-755.1	Polydactyly, Syndactyly
	755.2-755.3	Limb Reduction Anomalies
	758	Down Syndrome
Category XIV	760-779	Certain Conditions Originating in the Perinatal Period

* The Ninth Edition of the International Classification of Disease (1992).

Appendix II. Mortality, Morbidity and Congenital Anomalies Rates (1986-1992) in the Windsor Area of Concern

Introduction

In November 1999, Health Canada (1998) released a set of reports on the health status of 17 sub-populations on the Canadian side of the Great Lakes. These 17 sub-populations lived in Areas of Concern (AOCs) designated as such under the Great Lakes Water Quality Agreement. One of these areas is the Detroit River, and, as part of its Great Lakes Health Effects Program, Health Canada compiled data and statistics on the health of the community residing in the following municipalities: Windsor; Amherstburg; Tecumseh, Sandwich West; Essex, Belle River; St.Clair Beach, Anderton, Malden, Colchester North, Sandwich South, Rochester and Maidstone. For the purposes of this report, the selected municipalities are referred to as the Windsor AOC.

The reports are valuable sources of data on the incidences of diseases and their statistical significance for each of the 17 AOCs compared with the rest of the province of Ontario. Data were selected by Health Canada on diseases that might be linked to exposures to contaminants in the environment. The reports provide quantitative data as a resource to professionals to investigate the health status of communities within the AOC and compare incidence rates with the rates in the rest of the population in Ontario. No attempt was made to explain causal relationships between exposures to contaminants and any specific health outcome. The objective was to provide a basis for forming hypotheses that could be further investigated.

Windsor residents are exposed to a variety of contaminants from a variety of sources. In addition to occupational exposures of the workforce to a variety of products during manufacturing, residents are exposed to a variety of pollutants discharged to the waters and emitted to the atmosphere in Windsor and Detroit, Michigan.

Congenital Anomalies and Infant Mortality

One of the health outcomes of particular interest to potential parents is the health of their newborn child. The Windsor AOC had 13,196 females born between 1986 and 1992. 779 of these had some kind of anomaly diagnosed within the first year. This was 25 percent higher than the rest of Ontario and included: 13 females born without brains, anencephalus, at a rate three times higher than the rest of Ontario; 149 girls born with heart defects, 56 percent higher; 95 with clubfoot, 69 percent higher; and 10 with reductions in the length of their limbs, 2.24 times higher. 93 girls died within the first year at a rate 24 percent higher than the provincial rate.

Similarly, there were 13,950 boys born between 1986 and 1992, and of this group, 885 had anomalies, 13 percent higher than the provincial rate; 24 had water on the brain, congenital hydrocephalus, at a rate 88 percent higher than the provincial rate; 172 had congenital heart defects, 65 percent higher; and 89 had clubfoot, 36 percent higher. 97 boys died within the first year at a rate that was comparable to the rest of Ontario.

From a statistical standpoint, it is impossible to determine whether the infants who died had a significantly elevated incidence of anomalies, but the table in the Health Canada report warns about or flags several conditions, including anomalies of the nervous system and heart, renal and urinary systems, circulatory and respiratory systems, and Down syndrome.

Mortality Rates and Morbidity Incidence, Based on Hospitalization Records, 1986-1992

The rate at which people die or go to the hospital can be taken as an indication of the overall health of the community. People in the Windsor AOC died at a significantly higher rate, males - 8 percent higher and females - 5 percent higher, than in the rest of Ontario. This increased mortality occurred significantly among people who were over 45 years old and for both males, 14 percent higher and females, 10 percent higher. The number of cases of people in the Windsor AOC hospitalized for all causes was about 15 percent higher for females and 21 percent higher in males than in the rest of Ontario.

In terms of infectious diseases, the people of the Windsor AOC had lower rates of mortality. Males tended, however, to have a higher incidence of morbidity from intestinal infectious diseases, 11 percent higher than provincial rate, particularly among those under 25 years old, 14 percent higher, and females had a 53 percent higher incidence of morbidity from viral hepatitis, particularly among females between 45 and 75 years of age, 73 percent higher.

In recent years there has been a growing appreciation of the effects of environmental contaminants on the functioning of

People in the Windsor AOC died at a significantly higher rate, males - 8 percent higher and females - 5 percent higher, than in the rest of Ontario. This increased mortality occurred significantly among people who were over 45 years old and for both males, 14 percent higher and females, 10 percent higher.

the endocrine and immune systems. While the incidences of mortality from this class of diseases in the Windsor AOC tended to be non-statistically above the provincial rates, the morbidity was of particular concern. For example, there were 314 cases of thyroid disease in females, representing a 24 percent increase over the provincial rate. In contrast to all the other 16 AOCs, the onset of the increased incidence of thyroid disease in females occurred in the Windsor AOC between birth and 24 years of age and this increase was more than two fold of the provincial rate. Further, there were elevated rates for thyroid disease in Windsor women occurring in all age categories, suggesting the possible presence of thyroid active agents in the Detroit/Windsor environment. Interference with thyroid function has recently been implicated in the structural and functional development of the fetal and infant brain with consequences for learning and behaviour.

Similarly, there are increased incidences of morbidity for diseases of other endocrine glands in both males, 41 percent, and females, 41 percent, over the provincial rate. In contrast to Hamilton and Toronto that had rates of diabetes 30-40 percent lower than the provincial rates, the rates in the Windsor AOC were 44 percent higher for males and 41 percent higher for females. In common with other relatively polluted locations, such as Thunder Bay, Sault Ste Marie, Spanish River and Niagara Falls, the onset of the increase in the incidence, 58 percent for males and 41 percent for females, in the Windsor AOC occurred between birth and 24 years old. These data indicated that there may be environmental pollutants that interfere with the functioning of the pancreas.

Similarly, in contrast to Hamilton and Toronto that had rates of ovarian dysfunction related to diseases of the endocrine system well below the provincial rate, the rate in the Windsor AOC was more than twice, 2.12 times, the provincial rate and comparable with the rates at Thunder Bay, 2.19 times, and Sault Ste Marie, 2.34 times, though not as high as at Spanish River, 5.84 times. There was an early onset of the hospitalization of women for ovarian dysfunction in the Windsor AOC and the increased incidence began in the group under 25 years of age.

In terms of morbidity as hospitalization from disorders of the metabolic and immune systems, both males and females had incidence rates that were more than 40 percent higher than the rest of the province. In males, the increased incidence, 30 percent higher, occurred among those under 25 years old. In males and females over 45 years old, the morbidity rate as hospitalization was respectively 47 percent higher and 61 percent higher, and rose for those over 75 years old to 60 percent and 94 percent. 46 females died of these disorders at a rate that was 33 percent higher than the rest of the province. The rate of mortality among females between 45 and 74 years old was 86 percent higher than the rest of the province.

The population in the Windsor AOC tended to have higher morbidity rates for diseases of the blood and blood-forming organs compared with the rest of Ontario. Males had a 29 percent higher incidence rate and the corresponding figure for females was 13 percent higher (See also section 4 below for mortality and morbidity from cancer of the lymphatic and hematopoietic systems). Among males between birth and 24 years old, the incidence was 68 percent higher than males of the corresponding age in the rest of Ontario. Males over 45 years old had rates that were 15 percent higher and among females over 75 the rate was 10 percent higher than the corresponding provincial rates.

There were several disorders of the nervous system and sense organs that exhibit significantly higher incidence rates in the Windsor AOC than in the rest of the province. The rate of hereditary and degenerative diseases of the central nervous system in both males and females was about 15 percent higher than the incidence rate for the rest of Ontario. For both males and females between 25 and 44 years old, the rate rose to 44 percent and 54 percent respectively above the provincial rate. Similarly, for other disorders of the central nervous system, the morbidity incidence rate was higher for males, 31 percent, and females, 21 percent, and rose to 54 percent above the provincial rate among women between 25 to 44 years old and to 40 percent above the provincial rate among men between 45 and 75 years old. The mortality rate for males between 25 and 44 years old was more than twofold, 231 percent higher than the provincial rate for disorders of the central nervous system. Disorders of the peripheral nervous system, such as muscular dystrophies and other myopathies, were about 45 percent higher than the provincial rates in both males and females, and among those between 25 and 44 years old the rate above the provincial rate rose to 99 percent higher for males and 81 percent for females. The rate of disorders of the eye was 21 percent higher among males and 11 percent higher than the provincial rate among those between 45 and 74 years old.

There are several diseases of the circulatory system for which the population in the Windsor AOC had a significantly higher incidence of mortality and morbidity than in the rest

of the province. Of particular concern was the rate of mortality for hypertensive disease in males that was 56 percent higher, and mortality from diseases of the arteries, particularly atherosclerosis that was more than two times higher than in the rest of the province for males, 2.23 times, and for females, 2.45 times. Other disorders of the circulatory system for which there was a higher morbidity than in the rest of the province include: hypertensive disease, about 40 percent higher, and ischaemic and other heart diseases, about 20 percent higher.

In terms of the incidence of diseases of the respiratory system, the community had more than a two fold increase over the rest of the province for mortality from chronic bronchitis in males (See also section 4 below for mortality and morbidity from cancer of the respiratory and intrathoracic organs). Elevated incidences of morbidity for other disorders of the respiratory system included: respiratory infections; pneumonia and influenza; chronic obstructive pulmonary disease, particularly, including chronic bronchitis, 77 percent higher, and asthma, 9 percent higher, in females. The number of cases of hospitalization for asthma between birth and 24 years of age between 1986 and 1992 was 1637 for males, 490 per 100,000 population, and 1239 for females, 380 per 100,000 population.

Among the diseases of the digestive system, mortality in males and females was about 40 percent higher than the provincial rate for diseases of the oesophagus, stomach and duodenum. Significantly elevated rates of morbidity over the provincial rates were evident for: diseases of the oesophagus, stomach and duodenum, 30 percent higher for males and 60 percent higher for females; noninfective enteritis and colitis, 70 percent higher for males and 46 percent for females; and other diseases of the intestines and peritoneum, 23 percent higher for males and 33 percent for females; and digestive system, 16 percent for males and 20 percent for females. Of particular concern was the increased rates compared with the rest of the province for these diseases among young males and females between birth and 24 years of age with rates about 70 percent higher than in the rest of the province (See also section 4 below for mortality and morbidity from cancer of the digestive organs and peritoneum).

Several of the rates of the incidences of morbidity from diseases of the genitourinary system in the population were elevated (See also section 4 below for mortality and morbidity from cancer of the genitourinary organs). There was more than a 60 percent increased incidence rate of diseases of the urinary system in both males and females and increased incidences occur in all age classes. Morbidity from disorders of the breast was increased in both males, 44 percent, and females, 30 percent. Morbidity as hospitalization cases for diseases of the male genital system was elevated 40 percent and for infertility was 55 percent higher than the rate in the

rest of the province and elevated incidence rates occur in all age classes. Similarly, morbidity from disorders of the female genital tract was elevated 14 percent. Morbidity from cases of hospitalization for females between 25 and 44 years old was elevated for endometriosis, 9 percent higher, and for infertility, 13 percent higher, compared with rates in the rest of the province.

There was a significantly elevated incidence of morbidity from inflammatory conditions and other diseases of the skin and subcutaneous tissues in both males and females and in all age classes. The incidences in males and females between birth and 24 years old were, respectively, about 60 percent and 30 percent higher than the rest of the province, but rose to about twice the provincial rate in 25 to 44 years of age.

The rates of morbidity as hospitalization cases for diseases of the musculoskeletal and connective systems in the population of the Windsor AOC were significantly elevated for the following: arthropathies and related diseases, 12 percent for males and 11 percent for females; dorsopathies, 26 percent for males and 21 percent for females; rheumatism, excluding the back, twofold increase for males and 88 percent increase for females; and osteopathies, chondropathies and acquired musculoskeletal deformities, 27 percent for males and 30 percent for females. These elevated incidence rates tended to occur in all age classes up to 75 years old. Five females between 45 and 74 died of diseases classified as osteopathies, chondropathies and acquired musculoskeletal deformities resulting in incidence rates more than threefold, 361 percent higher than the provincial rate.

Cancer Mortality and Morbidity

The following is a description of the cancer mortality and morbidity based on the health data and statistics for the period 1986-1992. In the intervening years, the incidence of cancer in the Windsor AOC may have increased. The incidence of selected cancers in the population was 4,275 cases for males and 3,941 for females. The incidence rate for males was seven percent above the rate for the rest of the

province. Among males and females between 45 and 74 years old, the elevated incidence rates of cancer morbidity were, respectively, 10 percent and 5 percent higher than the provincial rates

The incidence rate for mortality from cancer of the lip, oral cavity and pharynx among people who were between 45 to 75 years old was 54 percent higher for males and more than twofold higher for females.

Of particular concern, however, was the increased rate of mortality from pancreatic cancer among both males, 49 percent higher, and females, 57 percent higher, particularly for those between the ages of 45 to 74. This significantly elevated mortality among this age group from pancreatic cancer was reflected in increased morbidity rates in males, 33 percent higher, and females, 40 percent higher.

Among the class of cancers of the digestive organs and peritoneum, there was a 10 percent higher incidence rate of mortality among males and 16 percent higher among those between 45 and 74 years of age than in the rest of Ontario. Much of this increased rate of mortality from cancer in males was attributable to cancer of the stomach, colon and rectum. Of particular concern, however, was the increased rate of mortality from pancreatic cancer among both males, 49 percent higher, and females, 57 percent higher, particularly for those between the ages of 45 to 74. This significantly elevated mortality among this age group from pancreatic cancer was reflected in increased morbidity rates in males, 33 percent higher, and females, 40 percent higher. In women, this increased morbidity rate from pancreatic cancer, 43 percent higher, persisted for those in the Windsor AOC for those over 75 years of age.

There were increased incidence rates for morbidity and mortality from cancers of the respiratory and intrathoracic organs for both males and females. The mortality and morbidity rates were elevated, respectively, by 17 percent and 19 percent in males and by 12 percent and 16 percent in females. Among males between 25 and 45 years of age, the rate of morbidity was 77 percent higher and the mortality was more than twice the provincial rate. Elevated incidence rates of morbidity from lung cancer were evident for males, 20 percent, and females, 17 percent, between 45 and 74 years of age.

In terms of cancers of the genitourinary organs, including the ovary, prostate, testis, bladder, kidney and other urinary organs, a statistically significant increase in morbidity was evident for bladder cancer in males, 19 percent higher, between 45 and 74 years of age. Mortality rates for males and females from all cancers of the genitourinary organs tended to be elevated even though they did not reach statistical significance.

There were three kinds of cancers of the lymphatic and hematopoietic (blood forming) system: Non-Hodgkin's lymphoma, Hodgkin's lymphoma and leukemia. There was more than a twofold higher, 226 percent, incidence rate for mortality from Hodgkin's disease in females and twofold elevated rates, though they were not statistically significant, occurred in all age categories. The rates of morbidity from leukemia was significantly elevated in both males, 33 percent higher, and females, 44 percent higher, between 45 and 74 years of age compared with the rest of the province.

Comparison With Hamilton, Ontario

Health Canada selected these health outcomes based on the plausibility that the outcome could occur as a result of exposure to environmental contaminants. Hamilton is another municipality with heavy manufacturing in southern Ontario, is designated as an Area of Concern, and might represent a useful comparison with the health data and statistics for the Windsor AOC.

The overall rates of congenital anomalies in the Hamilton population were 20-30 percent lower than the Ontario provincial rates and thus the rates for males in Hamilton were 35 percent lower than in the Windsor area and 53 percent lower for girls. Such contrasts might indicate the presence of contaminants in the Windsor environment that might be increasing the rates of congenital anomalies.

There was a marked contrast between Windsor and Hamilton in terms of the morbidity as hospitalization in relation to diseases of the endocrine, nutritional, metabolic and immune systems. The Windsor population experienced higher incidence rates than the provincial rates for diseases of the thyroid, diabetes, ovarian dysfunction and for metabolic and immunity disorders, whereas the Hamilton population exhibited much lower incidence rates. While the increased mortality rates for endocrine and immune diseases in the Windsor population may not be statistically significant compared with the rest of the province, they contrasted with the rates in the Hamilton population that were significantly lower than the provincial rates. There was a similar marked contrast between these two Areas of Concern in terms of the incidence rates for diseases of the blood and blood-forming organs.

In terms of the diseases of the nervous systems and sense organs, the population in the Windsor AOC showed markedly elevated incidence rates for diseases of the central and peripheral nervous systems and disorders of the eye in both males and females. In contrast, Hamilton had an increased rate only for diseases of the peripheral nervous system in females and for infantile cerebral palsy in females.

The incidence rates for certain circulatory diseases was the only category for which Hamilton had comparable disease incidence rates. For example, there were higher rates of atherosclerosis in Hamilton versus Windsor males, respectively 91 percent versus 61 percent higher than the provincial rate, and comparable rates in females, 63 percent versus 66 percent higher than the provincial rate. There were also possible concerns about the slightly elevated incidence rates for ischaemic heart disease compared with the provincial rates in Hamilton males, 1 percent higher, and females, 3 percent higher, and for pulmonary circulation in females, 12 percent higher. But these contrast with the markedly elevated incidence rates in Windsor for males and females for hypertensive disease, respectively 41 percent and 36 percent higher; ischaemic heart disease, 18 percent and 36 percent higher; diseases of the pulmonary circulation in males, 18 percent higher; other forms of heart disease in males and females, 14 percent and 23 percent higher; and diseases of the arteries, arterioles and capillaries, 29 percent and 27 percent higher. These contrasts in the measures of morbidity from circulatory diseases in the Hamilton and Windsor populations are reflected in the mortality rates in the respective communities. There was a similar marked contrast between the incidence rates for Hamilton versus Windsor for the respiratory systems in both males and females. Rates in Hamilton for acute respiratory infections and other diseases of the upper respiratory tract, pneumonia and influenza and for chronic obstructive pulmonary diseases, including chronic bronchitis, emphysema and asthma, were markedly below the provincial rates in contrast to those in Windsor that were significantly elevated.

Similar contrasts in incidence rates between the two Areas of Concern were evident for morbidity as hospitalization for diseases of the digestive and genitourinary systems and for inflammatory and other conditions of the skin and subcutaneous tissues and for diseases of the musculoskeletal and connective systems.

Similar contrasts between Windsor and Hamilton were evident for the cancer morbidity and mortality rates. In Hamilton, there were no categories of cancer for which there was an elevated incidence rate for morbidity that was statistically significantly. However, there were several, such as the morbidity rate for cancer of the colon and rectum, prostate, and female genitourinary organs that were significantly lower than the provincial rates. In Windsor, there were significantly elevated rates of morbidity from cancer of the pancreas and of the intrathoracic organs in males and females, and of the bladder and of leukemia in males. Females had significantly lower rates of cancer of the oesophagus and melanoma of the skin.

Similarly, mortality from cancer was elevated in the Windsor population compared with the Hamilton population. In the Hamilton data base, there was a significantly elevated incidence of cancers that were unspecified in both males and females making direct comparison difficult. Mortality in males in Windsor was significantly elevated for cancers of the lip, oral cavity and pharynx, and for cancer of the colon and rectum. Mortality from pancreatic cancer was significantly elevated in males and females in the Windsor area. While males in Hamilton died from cancers of the intrathoracic organs at an elevated rate, 6 percent higher, compared with the rest of the province, the mortality rates in Windsor tended to be 10 percent higher and the rate for females became statistically significant compared to the rate in the rest of the province.

Conclusion and Recommendation

Based on the health data and statistics for those health outcomes that might be related to exposures to environmental contaminants, the population living in the Windsor Area of Concern experienced the following: a higher incidence of cancer; a higher rate of hospitalization for a variety of diseases; and their infants had a higher incidence of congenital anomalies than the rest of the province. Because no specific causes of these increased incidence rates of these health conditions have been identified in the Windsor Area of Concern, as a precaution, every measure should be taken to reduce exposures to environmental contaminants whether the exposure route is from occupation, water, air or food, or from dust.

1999-2001
Priorities Report
Chapter 3

The Council of Great Lakes Research Managers

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3.1 INTRODUCTION

The Council of Great Lakes Research Managers (Council) serves as the International Joint Commission's (IJC) principal advisor on research programs and needs. The Council's purpose is to enhance the ability of the IJC to provide effective leadership, guidance, support and evaluation of Great Lakes research as it applies to the provisions of the Great Lakes Water Quality Agreement. The Council's responsibilities include:

- promoting effective communication and collaboration between researchers and agencies in Canada and the United States;
- encouraging researchers to share their findings;
- compiling a summary of current and planned research programs related to the Great Lakes Water Quality Agreement, particularly those called for by Annex 17;
- identifying and prioritizing research needs to identify gaps and encourage the U.S. and Canadian governments, the parties to the Agreement, to shift funding toward studies directly relevant to the Agreement's purpose; and
- reviewing the impact of research recommendations made by itself, the Great Lakes Science Advisory Board, the Great Lakes Water Quality Board and the IJC.

Membership is evenly divided between representatives from the United States and Canada, consisting of individuals managing federal, state and provincial research programs and representatives from academic institutions and private industry. Binational members representing the Great Lakes Fishery Commission and the International Association for Great Lakes Research also sit on the Council.

The Council and Great Lakes Science Advisory Board engaged in a methodical evaluation of emerging issues to identify priority issues for the 1999-2001 priority work cycle. *(See section 2.4 of the Great Lakes Science Advisory Board chapter for a detailed process description.)* Six priority issues were identified for investigation of research needs: ecoiogical impacts of changing demographics; impacts of water level fluctuations; emerging contaminants including pharmaceuticals; ground water; alien invasive species; and emergence of new pathogens. One additional issue identified as an area of shared interest between the Council and Science Advisory Board was the need for an integrated Great Lakes observing and monitoring system. As a result of this shared interest, the two groups formed a joint subcommittee to address this issue.

The Council evaluated each issue by forming subcommittees to 'scope out' each issue. The process of scoping involves: 1. determining the current level of scientific knowledge on a priority issue; 2. identifying gaps in knowledge; and 3. ranking research needs to fill those gaps.

Five of these issues were examined and the results provided. Further discussion, study and workshops are planned regarding the emergence of new pathogens and the need for an integrated Great Lakes observing and monitoring system. These future activities are discussed in sections 3.8.3 and 3.8.4 respectively.

The process of scoping involves:

1. determining the current level of scientific knowledge on a priority issue;
2. identifying gaps in knowledge; and
3. ranking research needs to fill those gaps.

The Council of Great Lakes Research Managers would like to acknowledge the efforts of all of those who, although they were not official members of the Council, made a significant contribution to the report. Many participated as invited experts at Council meetings, authored special reports, served as alternate representatives and provided valued support. They include: Jacinthe Leclerc, Bill Cibulas, Heraline Hicks, Rao Manam, Dan Todd, Sheridan Haack, Sergei Chenyak, Allegra Cangelosi, Walter Rast, Joseph Gilbert, Tom Crane, John Gannon, John Freidhoff, Bill Booty, Dave Dolan, Miriam Diamond, Ken Drouillard, Russ Kreis, Heather Morrison, Jan Ciborowski, Lisa Tulen and Giovanna Stasiuk.

3.2 ECOLOGICAL IMPACTS OF CHANGING DEMOGRAPHICS WITHIN THE GREAT LAKES BASIN

3.2.1 Background

The Great Lakes basin is home to 33.5 million people, with approximately 8.5 million in the province of Ontario and the remaining 25 million distributed among the eight Great Lakes states. Population density is highest in the southern part of the basin and around lakes Michigan, Erie and Ontario. The greater Toronto metropolitan area, located on Lake Ontario, accounts for almost half of the Canadian basin population, whereas approximately 80 percent of the U.S. basin population is located in its 11 largest metropolitan areas.

Human beings are the single largest source of stress to the Great Lakes basin ecosystem. Understanding how human populations may change over future decades may help environmental managers anticipate and deal with emerging environmental problems that result from changing demographics.

The many forms of development, such as industrial, commercial, residential, agricultural and transportation-related activities, carry specific, significant and cumulative impacts for the natural world and particularly Great Lakes water quality. These activities take place throughout the basin, but their most immediate and direct impact on the Great Lakes appears to be on lands proximate to the lakes themselves and their tributary waters. Land use in coastal areas is changing in response to the region's evolving economy and industrial restructuring, as well as to the relentless forces of urban sprawl. The aesthetic and recreational attraction of the shore also is spurring renewed public appreciation and use of this asset, whether it be an urban waterfront or remote location. Mining and forestry activities, on the other hand, which are concentrated in the northern half of the basin, are likely to remain relatively stable into the future.

Although there has been some improvement to air pollution from industrial sources, air quality, especially ground level ozone, affecting living organisms in the nearshore ecosystem is a major concern. As urban transportation systems become more energy intensive, this problem could intensify. Increasing greenhouse gas releases continue to pose a challenge, as more and more vehicles congest roads transporting people to and from work at ever increasing distances.

3.2.2 Urban and Rural Development Land Uses

Urban Sprawl

The most significant development issue in the Great Lakes region is the continuing growth of major metropolitan areas and the virtually uncontrolled sprawl of low-density, residential areas and other development. The detrimental consequences of these trends are well known. The population-related generation of pollution, higher transportation and residential energy use, increasing encroachment on agricultural lands and natural areas, and burdensome physical infrastructure requirements portend an unsustainable future.

Today, urban sprawl is the predominant pattern of development on both sides of the border. Land-use projections for the state of Michigan, for example, indicate that a state population increase of less than 12 percent may result inasmuch as an 87 percent increase in new developed land by the year 2020. A six percent population increase in southeastern Michigan alone is expected to result in a 40 percent increase in land consumption during this same period.

Land and water availability, lower wage scales, transportation access, proximity to new residential markets and other cost/service factors have accelerated sprawl. The central city anchor for rail transportation, multi-story factories, and apartment life has given way to interstate truck transport, one-story industrial buildings, sprawling office parks, and a house and lot of one's own. An ongoing pattern of tax-based subsidies to developers by municipal governments, eager to see growth at any cost, has to date served to constrain market forces that could reverse this trend.

There has been a significant trend toward the extensive construction of seasonal, second homes and recreational cottages. This trend is now shifting toward permanent residences in rural areas as the leading edge of the baby boom generation approaches retirement age. The emerging trend toward multiple careers over one's lifetime and more home-based work for the new 'information' generation allows greater workplace mobility.

Land classified as farmland, which includes cropland, woodland and permanent pasture categories, declined in the Great Lakes basin by more than 1.83 million hectares (4.52 million acres) or 9.6 percent between 1981-82 and 1991-92.

Much of this land conversion has taken place near the metropolitan population centres, but the phenomenon is occurring in more remote rural areas where residential, commercial, industrial and transportation development pressures also exist. Land consumption caused by sprawling development has been a dominant post-war trend and, in some places, has eliminated important wildlife habitat and good agricultural land.

If significant levels of farmland conversion continue in the Great Lakes basin, the agricultural production base will decline, and with it, the agrifood sector of the economy. With nearly two-thirds of basin cropland located within 50 kilometres of medium-sized cities and large metropolitan areas, efforts to preserve farmland may also help to contain sprawling development patterns and improve sustainability.

Brownfields

The economy of the Great Lakes region is completing a transition from heavy manufacturing to a more diverse and increasingly service-oriented economy. This restructuring has resulted in a surplus of vacant industrial locations that require environmental cleanup before they can again become productive. Referred to as 'brownfields,' these vacant or inactive industrial or commercial properties were once thriving manufacturing operations and have now become blighted areas of neglect and often have known or suspected soil or water contamination problems. These properties pose a unique opportunity and challenge for the development industry, government environmental agencies and the banking industry, which must weigh the financial rewards of new development against the increased cost and potential environmental liability of providing loans to those undertaking redevelopment of these sites. New development is rejected for many reasons, including cleanup costs and lingering uncertainty over liability issues, thus encouraging such development to migrate to outlying undeveloped areas or greenfields.

The retreat of industry from its traditional location along the nearshore presents new opportunities for waterfront and harbour redevelopment as communities become involved in grass-root efforts to 'take back the waterfront' for public and commercial uses. Redevelopment of these former industrial sites also presents new opportunities for high-technology manufacturing, commercial service, residential construction and leisure activity or some mix of these for tomorrow's economy. Redeveloped brownfields represent opportunities to make urban areas more efficient by utilizing existing infrastructure. Impact fees and development charges, which developers pay for the cost of new infrastructure for development, may also serve as an incentive for the redevelopment of brownfields. A surcharge on these fees could be scaled and put into a brownfields redevelopment fund for that purpose. This approach would forestall sprawl and development in rural areas by encouraging greater use of metropolitan sites. Alternatively, a portion of the tax increment from new metropolitan development could be used to purchase open, green space or, in the case of farmland, the purchase of development rights.

Hardening of the Landscape and Stream Degradation

Impervious or 'hardened' surfaces, such as roads, parking lots, sidewalks and rooftops, block rain from recharging ground water and drinking water supplies, impair the ability of natural systems to cleanse runoff and protect wetlands and nearshore biota from contaminants, increase the potential for flooding and erosion, and contribute to the degradation of streams and lakes. Stream degradation caused by development is a classic example of both long-term cumulative environmental change and the difficulty of responding to such change. For example, of the more than 63,000 hectares (156,600 acres) that comprise metropolitan Toronto, only one-quarter remains agricultural, vacant land or open space.

Another form of hardening takes place along the lake shores and tributaries when shoreline residents act to protect their real estate from wave and flood damage by hardening the shoreline with concrete, gabion and other shoreline covering. Extension of shoreline protection, sometimes coupled with piers and abutments, alters natural functions along the shoreline. This has been the case for much of the north shore of Lake Ontario and has led to the permanent loss of once productive beaches.

3.2.3 Agricultural Land Uses

About one-third of the land in the Great Lakes basin is used for agriculture, with usage concentrated in the southern half of the basin. Nearly three-quarters of the basin's agricultural land is on the U.S. side. There is a trend toward fewer, but larger farms with more intensive crop production, declining livestock numbers and less land overall in agricultural production. From 1981 to 1992, basin farmland declined by almost 10 percent and cropland by almost six percent. The conversion of agricultural land to development, in addition to other global and continental competitive pressures, is causing a shift of agricultural activities to areas with less productive soils, shorter growing seasons and greater distances to major markets.

Increasing environmental awareness among the public and farmers is resulting in a growing market for pesticide-free agricultural produce. At the same time, farmers are switching to environmental conservation practices, such conservation tillage, integrated pest management, and better manure management techniques. The ramifications of an emerging trend to greater dietary substitution of fruits and vegetables instead of animal products, in response to the apparent health risks associated with meat products, have yet to be felt to any significant extent. One consequence may be greater produce farming at the edge of cities as increasingly sophisticated consumers demand more locally grown and fresher vegetables.

3.2.4 Conclusions

Rapid population growth, intensive industrial and agricultural activity and sprawling urban development have resulted in significant stress to the nearshore ecosystem of the Great Lakes. Nearshore waters continue to be polluted, and in some cases have become severely contaminated, from sanitary sewage, industrial toxic substances and urban and agricultural runoff.

Wetlands and other natural habitat areas within the nearshore ecosystem are under threat of destruction and alteration by increasing urban sprawl and second-home cottages. Finally, shoreline protection and other shore hardening caused by development have interfered with natural shoreline processes and, in some cases, resulted in the irreversible loss of beaches.

Notwithstanding recent attention to more intensive forms of urban development, development throughout the basin continues to be predominantly land-intensive urban sprawl. By contrast, high-density intensive development facilitates the economic viability of public transit as an efficient alternative to the private automobile for commuters. Urban communities with higher population densities typically require less costly municipal infrastructure, such as sewers and roads, use less water and energy, and create less pollution. As a result, taxation to pay for municipal services may be significantly lower, making higher-density communities more competitive from that perspective.

Reduced use of natural resources generally implies reduced pollution and stress on ecosystems, including the nearshore ecosystem. Urban sprawl has contributed to the loss of some of the best farmland in the basin, as housing and other development replaces agriculture. Farming that shifts to lower productivity soils and at greater distances from final markets is less efficient and more resource-intensive. In addition, urban sprawl promotes the clearing and conversion of natural habitat lands, including wetlands.

Urban sprawl has contributed to the loss of some of the best farmland in the basin, as housing and other development replaces agriculture. Farming that shifts to lower productivity soils and at greater distances from final markets is less efficient and more resource-intensive.

Finally, marketplace incentives that would promote more sustainable development, such as full cost, user-pay development charges or impact fees, are inconsistently applied by different jurisdictions. At the same time many jurisdictions believe they should compete for the short-term jobs and tax revenues that come from new development. Direct and indirect subsidies for new development through the public provision of roads, water and sewage treatment facilities mask the real long-term economic and environmental consequences of urban sprawl and continue to favour unsustainable development.

3.3 EMERGING CONTAMINANTS AND PHARMACEUTICALS IN GREAT LAKES WATERS

3.3.1 Background

The Great Lakes Water Quality Agreement charges the governments of the U.S. and Canada, the parties to the Agreement, to "restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes Basin Ecosystem." In particular, Annex 1 addresses persistent toxic substances in several organic and inorganic chemical classes and Annex 10 charges the Parties to maintain lists of known or potential "hazardous polluting substances" with a risk of being discharged to the Great Lakes ecosystem. The main focus of the Parties has been on these priority persistent and hazardous pollutants. However, chemicals specifically listed in the Agreement and its annexes constitute only a portion of the greater discharge of substances into the Great Lakes. Recently, other industrial chemicals, known to mimic various endocrine functions, have received attention. Little attention, however, has been given to several, more diverse groups of substances that are now being detected with greater frequency in waters both regionally and world-wide. This includes pharmaceutical agents and the bio-active ingredients in a wide variety of personal care products.

In the last 10 years, several studies from Europe have reported the detection of several prescription and non-prescription drugs and household products in sewage treatment plant effluents, surface water and ground water (Buser 1998, Buser 1999, Herberer 1997, Holm 1995, Stan 1994). First thought to be only isolated occurrences, as more investigations are done and the detection limits lowered, the range of substances detected has expanded and now encompasses the full gamut of prescription and non-prescription drugs and numerous household and personal care products (Halling-Soorenson 1998, Richardson 1985).

3.3.2 Widespread Use and Lack of Regulation

Over the past several decades, while attention has been focused on the many priority pollutants, this wide variety of substances have been overlooked. However unfortunate, this is in keeping with the lack of environmental regulation for most of these substances and acknowledges that, chemically, many of them are quite different from the persistent pollutants.

Many of these chemicals are typically not regulated or monitored in the environment. Also, few requirements exist for reporting total amounts manufactured, distributed, used or disposed of by the either the manufacturer or consumers.

Amounts used

Many of these chemicals are typically not regulated or monitored in the environment. Also, few requirements exist for reporting total amounts manufactured, distributed, used or disposed of by the either the manufacturer or consumers. This also reflects the proprietary nature of these substances and the numerous consumer formulations in use today. The 'sudden' detection of these contaminants is basically an increased awareness of their previously overlooked presence.

Another reason for their increasing detection is the acknowledgment of their widespread and ever increasing use. As urban and suburban populations continue to increase in number and, in turn, their use of these substances, it is more likely they will appear more frequently in impacted water supplies (Raloof 1998, 2000). The National Research Council recently reviewed this topic (NRC 1999) and, similarly, a report was recently released documenting an increase in the use of antibiotics in humans and in animal agriculture, and calling for more judicious use of antibiotics, especially in reference to an increasing resistance to many of them (Mellon 2001). The public health implications of this problem is being addressed by a U.S. task force on antibiotic resistance (CDC 2000).

Disposal

Another reason as to why these compounds are now being detected is the inconsistent regulation of their disposal. Although the disposal of almost all these compounds is well-regulated as industrial wastes during the manufacturing process, little attention has focused on their consumer-based, household disposal. Many chemicals, such as pharmaceuticals or fumigants used in households, reach sewage treatment

plants where little is understood about their removal and destruction, and where there are no monitoring requirements for these specific constituents. In other cases, chemicals may reach surface and ground waters as runoff from environmental applications, such as the use of antibiotics in confined animal feed operations or fruit tree agriculture, and from the constituents found in suntan lotions, insecticides or repellants found in personal care products.

In the absence of monitoring for these constituents in runoff or in surface or ground water, it is difficult to ascertain their presence and the potential degree of impact from various sources. Similarly, there is no requirement that these substances be monitored in source or finished drinking water.

Monitoring Occurrence

Initial reports from Europe found chemicals from a wide number of groups of substances in surface water and sewage treatment plant effluents (Halling-Soorenson 1998, Daughton 1999). Because of their reportedly low concentrations and chemical differences from the priority pollutants in the Great Lakes Water Quality Agreement, analysis for many of these substances is not yet routine, which complicates establishing simple monitoring programs. To date, only a few reports have appeared documenting their presence in North American waters. However, in 1999, the United States Geological Survey's (USGS) Toxic Substances Hydrology Program began a national reconnaissance for selected emerging contaminants (USGS 2000). This program is analyzing surface and ground water samples taken from a network of streams and wells across the U.S. for the substances listed in Table 1.

Current U.S. Geological Survey Activities

The Toxic Substances Hydrology Program of the USGS has implemented a national reconnaissance to provide baseline information on the potential environmental occurrence of select 'emerging contaminants.' More information on this program is available at their web site at http://toxics.usgs.gov/regional/emc.html (USGS 2000). Target analytes are in three categories: human and veterinary pharmaceuticals; industrial and household wastewater products; and sex and steroidal hormones. During 1999, a network of 100 stream sites was sampled, representing a wide variety of geographical and hydrogeological settings. The streams represent basins that fall into four general categories: intense urban activities; intense livestock production; mixed land use; and control streams. The sampling points were located in 24 states throughout the U.S. An additional 55 sites were sampled in 2000 to confirm and expand results.

To determine if emerging contaminants are being transported to ground water, 45 wells located in 16 states were also sampled during 2000. As part of this study, locations were sampled that are tributary to the Great Lakes in Michigan, Ohio and Wisconsin. The samples are being analyzed at USGS research laboratories that are developing, and/or refining the laboratory methods to measure these compounds to very low levels, less than one part per billion (ppb). Results are anticipated to be released in mid- to late-2001. This reconnaissance will provide: 1. the first nationwide assessment of the occurrence of these emerging environmental contaminants in streams and ground water; 2. a focal point for development and testing of new laboratory analytical methods for measuring compounds in environmental samples at very low, sub-ppb levels; and 3. a basis for design of more systematic monitoring programs for emerging environmental contaminants.

For several years, USGS has offered analysis of various compounds that can occur in wastewater and may indicate the possibility that other emerging contaminants may be detectable. These compounds include detergent metabolites, antibiotics, caffeine, cotinine, cholesterol, coprostanol, fumigants and other substances listed in Table 1.

3.3.3 Ecological and Human Health Impact

It must be recognized that a substantial number of these substances are manufactured to intentionally be biologically active, although at concentrations and in formulations that vary greatly from those detected in water. Since many pharmaceuticals are originally intended to suppress or kill infectious agents, or modify human physiology, their potential presence in water must be taken seriously. Also, it is reasonable to assume that they may have similar effects on unintended organisms, either directly or indirectly. Just as many industrial chemicals have been found to have unintended biological activity after being studied in a wider range of tests, it is not surprising that a number of these substances have had unintended biological effects.

Since many pharmaceuticals are originally intended to suppress or kill infectious agents, or modify human physiology, their potential presence in water must be taken seriously.

Table 1 List of Selected Categories and Examples of Substances

COMPOUND NAME	USE
Detergent Metabolites	
nonylphenol (total)	Nonionic detergent metabolite
nonylphenol ethoxylate 1(NPEO1) (total)	Nonionic detergent metabolite
NPEO2 (total)	Nonionic detergent metabolite
1,3-dichlorobenzene	Fumigant
octylphenol ethoxylates (1&2 Eos)	Nonionic detergent
Fumigants/Fragrances	
1,4-dichlorobenzene	Fumigant
1,2-dichlorobenzene	Fumigant
acetophenone	Fragrance
naphthalene	Poly aromatic hydrocarbon (PAH), fumigant
D-limonene	Fumigant
Disinfectants	
phenol	General disinfectant
triclosan	Disinfectant/Antimicrobial
Additives	
2,6-di-tert-butylphenol	Antioxidant
2,6-di-tert-para-benzoquinone	Antioxidant
butylated hydroxyanisole (BHA)	Antioxidant
butylated hydroxytoluene (BHT)	Antioxidant
benzaldehyde	Flavor
Animal sterols	
cholesterol	Principal sterol of animals
3ß-coprostanol	Sterol of carnivorous animals
Insect Repellent	
N,N, diethyl-m-toluamide (DEET)	Mosquito repellant
Drugs General	
1,7-dimethylzanthine	Caffeine metabolite
Acetaminophen	Analgesic
Caffeine	Over the counter stimulant and food component
Cimetidine	Stomach acid reducer
Cotinine	Degradation product of nicotine
Dehydronifedipine	Metabolite of nifedipine, a vasodilator
Digoxigenin	Cardiac regulation
Diltiazem HC1	Angia medicaton
Enalaprilat	Active antihypertensive metabolite of Enalapril
Flouxetine HC1	Antidepressant
Furosemide	Edema associated with congestive heart failure
Gemfibrozil	Lipid/cholesterol regulator
Ibuprofen	Over the counter analgesic
Lisinopril	Antihypertensive
Metformin HC1	Glycemic control
Paroxetine metabolite	Secondary caffeine metabolite
Ranitidine HCL	Stomach acid reducer
Salbutamol	Bronchiodilator
Warfarin	Anticoagulant for thrombosis and pulmonary embolism

Table 1, cont'd

COMPOUND NAME, USE
Drugs - Antibiotics
Examples:
Amoxicillin
Carbadox
Chlortetracycline
Ciprofloxacin
Erythromiycin
Ivermectin
Penicillin
Roxarsone
Sarafloxacin
Spectinomycin
Streptomicin
Sulfamethoxazole
Tetracycline
Timethoprim
Tylosin
Vancomycin
Virginiamycin

Intended Pharmacologic and Toxicologic Activity

Many of the substances considered were developed because they have specific pharmacologic mechanisms that address certain important health issues. Although these same substances may also have unintended effects in humans, known as side effects, their use is considered to be an acceptable risk because of the profound life-saving and life-sustaining intended effects. However, their potential biological activities usually have not been taken into consideration concerning disposal into sewers and water systems.

Two cases in point are the antibiotics and the estrogen-like compounds. The widespread use of antibiotics, particularly in confined animal feed operations and accounting for the major use of this group of substances, has been the subject of wide debate (Mellon 2001) and the focus of a U.S. task force (CDC 2000). It is thought the lack of monitoring of their use and disposal is part of the supposed cause of resistant bacteria, an unintentional outcome of their intended use. The case with estrogen-like substances is more complex. The use of estrogen-like substances is increasing with little consideration given to their disposal. It is likely that in our water systems, they can have direct actions based upon their structures that go beyond their intended use. Furthermore, a large group of other substances also reportedly have estrogen-like effects. These, and other substances now thought to have some estrogen or endocrine-like activity, could be having unintended actions on unintended audiences.

Another concern is the little understood result of combined or cumulative activity of very small amounts of these separate, but pharmacologically similar substances when in the presence of each other. The possibility of additive or synergistic effects for substances with similar or related mechanisms of action are not at all understood. More needs to be known about the levels of exposure that may be occurring and the activity of these substances in other organisms and ecosystems (Boudou 1997).

Relative Activities and Concentrations

A major aspect of this issue is the relative concentration in the source of exposure (water) compared to what might be a typical concentration range in humans leading to a desired biological effect. For humans we might attempt to use the

Table 2 Relative Concentrations in Water in Selected Locations Versus Typical Therapeutic Concentrations

SUBSTANCE	ENVIRONMENTAL WATER CONCENTRATION	THERAPEUTIC BLOOD CONCENTRATION
Tetracyclines	1 ug/liter	2 ug/ml
Erythromicyn	1 ug/liter	1 ug/ml
Indomethacin	10 - 100 ng/liter	0.3 - 300 ug/ml
Ibuprofen	10 ng/liter	300 - 400 ng/ml
Diazapam	5 - 100 ng/liter	10 ug/ml

The concentration values are shown in nanogram (ng) or microgram (ug) amounts per liter or milliliter (ml), as indicated. The values for water concentration were taken from Halling-Soorensen, 1998, and the values for the therapeutic concentration were taken from Goodman and Gilman, 1990.

concentrations found during normal therapeutic use. The concentrations found in a few selected locations in the environment and their normal therapeutic (blood) concentrations are provided for some representative substances in Table 2. It is important to note that many of these substances do not usually bioaccumulate in humans, designed appropriately so, such that their chemical structure allows the human body to eliminate them over a short period of time. However, numerous factors, such as the potential for bioaccumulation, especially in other species, and the amount of uptake from such an exposure, would be required in order to accurately assess the potential for relative harm from a given source. Factors, such as accumulation potential, length of exposure, greater sensitivity or unexpected biological effects could easy modify the therapeutic range (biological endpoint) and thus the relative concentration.

The relative concentration between the two columns in Table 2. is in a range of 100 to 1000 times higher in blood (in order to produce a therapeutic effect) versus the water concentrations detected in the few isolated studies to date. This does not take into consideration a wide array of factors that might effect these two values and their relative ranges, but does indicate that a two to threefold order of magnitude might exist in humans for the specific examples given here. Such a simplified risk assessment is indeed very basic and although it may suggest that a safety factor may exist, not enough data exists at this time to be able to justify any solid conjecture. Also, this two to threefold order of magnitude may only exist for the effects in humans, while other impacted species may show a greater susceptibility for a biological endpoint of toxicity and thus a smaller relative range between the exposure and biological-endpoint concentrations.

Ecological Activities

Beyond the intended actions and uses of these substances in human populations, due consideration must be given to their impact on other parts of the Great Lakes ecosystem. There is no doubt that exposure to low levels of some substances can have profound effects on other groups of organisms (Boudou, 1997). Besides the recently acknowledged reports of the development of antimicrobial resistance to an increasing number of antibiotics (CDC 2000), a few reports have shown that aquatic organisms are being affected in streams in North America following exposure to previously unsuspected pollutants (Raloof, 1998, 2000). Further evaluation of the occurrence and activity on other species is needed.

Public Health Impact

It is clear that past experiences with the priority pollutants must help shape an appreciation of the potential implications of these new chemical substances. Unfortunately we have little information on which to base any projections about the ultimate fate or long-term effects on humans or other parts of the ecosystem.

3.3.4 Research Goals

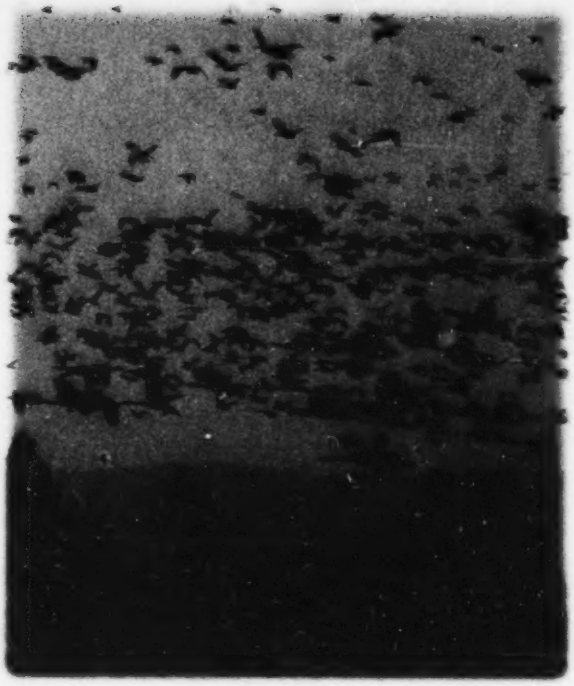
Further understanding of the extent of this problem will require action in three major areas. First, greater attention must be drawn to the problem such that an accurate assessment of the current status of these substances in Great Lakes waters can be done. This would be accomplished primarily through more monitoring of various water systems. Secondly, we must obtain a better understanding of the fate of these substances in soil and sediment and in waterways and water systems. Finally, after a better understanding is obtained of the levels of these substances in Great Lakes waters, further evaluations of the pharmacologic and toxicologic activities must be done to permit some estimation of the risks involved to exposure at those levels.

Monitoring

The primary goal of early efforts must be to assess the extent of the problem by doing accurate and thorough monitoring of possible routes of exposure. Since these substances can be substantially different, chemically, from the standard priority pollutants, methods for monitoring them can be considerably more complex and the amount of time necessary to analyze them increased. Establishing a unified approach to determining levels may require standardization of techniques and coordination of resources. As noted earlier, USGS currently has the only current ongoing monitoring program in place to begin to assess the presence of these substances in our waters (USGS 2000). A few studies have been reported by various groups at a symposium in Canada (personal communication).

Environmental Fate

Another difficult aspect of assessing the impact of these substances is determining their environmental fate. These substances may be entering water from a number of points, including sewage treatment plant effluent. The breakdown of these substances in the environment, often referred to as metabolism within organisms, and in the sewage treatment plant is not well understood because of the chemical



complexity of these substances. Even less is known about their binding characteristics to the parts of the environment where they are most likely to come in contact or the likelihood that they may bio-accumulate in some organisms. The extent of their binding is important in determining their fate as well as the extent of exposure to exposed organisms.

Biological Activity

Although the biological effects of some of these substances is well studied in man, their intended target in many cases, little is known about long-term exposures to low levels, the susceptibility of sensitive populations and the effects on other organisms. Certain water-based organisms are likely to be the most impacted by long-term exposure. However, until the extent of the exposures or levels can be estimated, little can be done to estimate the risks associated with the presence of these substances in the environment.

3.3.5 Recommendation

The Council recommends the following to the IJC.

- **Based on the information found in section 3.3 of the *1999-2001 Priorities and Progress under the Great Lakes Water Quality Agreement*, recommend to the Parties that the following areas of research and action be implemented regarding emerging contaminants and pharmaceuticals in Great Lakes water:**

a. **examine inputs to and outputs from wastewater and drinking water treatment plants to determine if emerging contaminants are present;**
b. **determine the effective levels, biotic indicators and degradation times for the emerging contaminants; and**
c. **identify viable options for wastewater and drinking water treatment plants to remove those chemicals identified as potential threats to human health and the ecosystem.**

(These conclusions may be best placed into action by framing them within the three research goals defined in section 3.3.4 for addressing the issue of emerging contaminants.)

3.4 UNDERSTANDING THE INTERACTION OF GROUND WATER AND SURFACE WATER IN THE GREAT LAKES BASIN

Recently, there has been a renewed interest in and a growing number of questions regarding the relationship of ground water to the Great Lakes. Understanding the interaction of ground water and surface water in the Great Lakes basin is essential to natural resource managers and scientists. In many ways, ground water and surface water are closely linked and need to be thought of as a single resource. Wise management of water resources in the Great Lakes requires an understanding that ground water is a large component of the Great Lakes water budget. Decisions that affect the quantity or quality of ground water discharge to tributary streams and coastal wetlands also affect the quantity and quality of water in the Great Lakes and the health of the Great Lakes ecosystem.

Both the International Joint Commission and the Great Lakes Protection Fund have supported recent research and white papers summarizing many of the significant issues regarding ground water and the Great Lakes.

Both the International Joint Commission and the Great Lakes Protection Fund have supported recent research and white papers summarizing many of the significant issues regarding ground water and the Great Lakes. Holtschlag and Nicholas (1998) provide estimates of indirect ground water discharge to the Great Lakes via tributary streams using streamflow records from the United States. Grannemann and Weaver (1998) present an annotated bibliography of selected references regarding ground water discharges directly to the Great Lakes. Grannemann and others (2000) summarize the major ground water issues in the Great Lakes region and identify information needs and research issues. Finally, ground water issues are highlighted by the IJC in its *Protection of the Waters of the Great Lakes*, including specific recommendations to the governments for ground water research.

The following summarizes ground water issues, including a reiteration of the research and information needs, and provides a prioritization and emphasis of those needs that are not widely recognized. The research needs are quite broad and encompass virtually all areas of the science of ground water hydrology.

3.4.1 Ground Water Issues Related to the Great Lakes

Quantity

Ground water enters the Great Lakes as either direct or indirect discharge. Direct ground water discharge is flow directly into a lake through the lake bottom. Indirect ground water discharge is flow into a lake by way of a tributary stream.

Most ground water discharged to the Great Lakes is indirect. Indirect ground water discharge ranges from 42 percent of the basin water supply for Lake Ontario to 22 percent for Lake Erie, excluding connecting channel flows. Ground water discharge to streams ranges from more than 75 percent of the total streamflow in Michigan to less than 40 percent in Ohio. Like streamflow, the amount of indirect ground water discharge is variable during the year, generally reaching a maximum in March or April and a minimum in August or February.

Lake Michigan is the only Great Lake for which there is enough information to estimate direct ground water discharge. There, it accounts for approximately five percent of the inflow budget. Direct ground water discharge to the remaining Great Lakes is most likely a smaller part of their inflow budgets.

The amount and timing of ground water discharge is affected by natural geologic and climatic conditions and by land use. Ground water discharge is usually greatest in undisturbed watersheds where subsurface materials are coarse and precipitation is high. Where land uses restrict recharge, such as in urban areas, ground water discharge is significantly reduced. Where land uses lower ground water levels, such as by pumping or by means of drainage tiles and ditches in agricultural areas, ground water discharge also is significantly reduced. In areas where ground water discharge is reduced, streams may have little or no flow during summers or other dry periods.

Quality

Ground water has a significant effect on the quality of water in streams tributary to the Great Lakes and on coastal wetlands by transporting natural and anthropogenic

There is a serious lack of research and information on ground water issues that encompass virtually all areas of the science of ground water hydrology. This research should be given high priority funding, given the direct impact of ground water quality on more than 20 percent of the basin's human population and a large biological community.

substances to them. In agricultural and urban areas of the Great Lakes basin, contaminants on the land surface become dissolved in ground water and eventually flow into streams, wetlands and the Great Lakes. This widespread, diffuse flow of contaminants by way of ground water is a type of nonpoint source contamination. Pesticides and nutrients, such as nitrate and phosphorus, are the principal nonpoint source form of pollution that reaches the Great Lakes by way of indirect ground water discharge to tributary streams and coastal wetlands.

Annex 16 of the Great Lakes Water Quality Agreement specifically addresses the flow of contaminated ground water to the Great Lakes. Annex 16 is generally interpreted as applying to point sources of contamination from specific sites, such as Areas of Concern. However, the language of Annex 16 does not exclude consideration of nonpoint source contamination via direct or indirect discharge.

Ecosystem

The Great Lakes ecosystem is closely tied to the biologic viability of tributary streams and coastal wetlands. The biologic viability of these, in turn, is largely dependent upon the quantity and quality of both surface runoff and ground water discharge.

Ground water discharge is a significant determinant of the biologic viability of tributary streams and coastal wetlands. In undisturbed areas, ground water discharge throughout the year provides a stable inflow of water with consistent dissolved oxygen concentration, temperature and water chemistry. Where land uses significantly reduce ground water flow to a stream, reaches of the stream or wetlands may lose their biologic viability. Likewise, where land uses add contaminants to a stream or wetland, they also may become unviable.

3.4.2 Identified Research Needs

The IJC, in its report, *Protection of the Waters of the Great Lakes*, makes the following recommendation.

Governments should immediately take steps to enhance ground water research in order to better understand the role of ground water in the Great Lakes basin. In particular, they should conduct research related to:

- unified, consistent mapping of boundary and transboundary hydrogeological units;
- a comprehensive description of the role of ground water in supporting ecological systems;
- improved estimates that reliably reflect the true level and extent of consumptive use;
- simplified methods of identifying large ground water withdrawals near boundaries of hydrologic basins;
- effects of land-use changes and population growth on ground water availability and quality;
- ground water discharge to surface water streams and to the Great Lakes, and systematic estimation of natural recharge areas; and
- systematic monitoring and tracking of the use of water-taking permits, especially for bottled water operations.

These recommendations are broad and generally include recommendations found in other reports cited in at the beginning of section 3.4. Depending upon the definition of research, some recommendations may not be considered research. For instance, the methods and approach to mapping hydrogeologic units are well developed and the lack of available maps is due to lack of funding for mapping, not a lack of understanding of how to map hydrogeologic units. Similarly, tracking bottled water operations does not constitute a research need.

There is a serious lack of research and information on ground water issues that encompass virtually all areas of the science of ground water hydrology. This research should be given high priority funding, given the direct impact of ground water quality on more than 20 percent of the basin's human population and a large biological community.

The Council has identified four specific research needs that have received little attention and should receive priority for research funding.

Effects of Land-use Change

Land use affects recharge rate and distribution, the amount and timing of ground water discharge to surface water bodies, and the quality of ground water, primarily via nonpoint source pollution. Where land use includes ground water pumping, such as for drinking water or irrigation, ground water may be subject to competing uses. There is

only a limited amount of research on the relationship of ground water quality to land use and virtually none on how land use affects recharge or discharge to surface water, therefore research is needed on these topics. There is a substantial amount of research and case studies related to ground water availability and competing uses, therefore, research on these topics is not a priority.

Ground Water and Ecosystems

Research focusing on the relationship of ground water and ecosystems is rare. Little is understood about the complex relationship among ground water, Great Lakes levels and coastal wetlands. While there is some research showing the importance of ground water in the hyporeic zone of streams, little is known about this relationship to stream and Great Lake ecosystems. The majority of Great Lakes fish spend some of their life in tributary streams dominated by ground water flow and it is important to understand these relationships.

Direct ground water discharge to the Great Lakes and coastal wetlands is poorly known and systematic research to estimate this discharge does not exist.

Estimating Consumptive Use

Consumptive water use rarely has been measured. It is typically estimated by coefficients of loss. There are two main consumptive uses -- irrigation and drinking water. The losses in irrigation are to evapotranspiration and incorporation into crop moisture content. The losses in drinking water are for public water systems where the water pumped from aquifers is discharged to streams, rather than aquifers, after treatment. These may not constitute a loss to the water balance of the Great Lakes, but they do constitute a loss from the ground water flow system and the beneficial discharge of ground water to surface water bodies. Irrigation consumptive uses have been measured by some field studies and models to estimate losses have been developed by researchers. Losses via drinking water systems have not been estimated, but can be readily estimated from water use data for public water supplies. These latter losses are important only for ecological implications, not for water balance calculations.

Discharge and Recharge

Ground water discharge to streams and the Great Lakes has been the subject of recent papers. However, the estimates of discharge to streams incorporate many broad assumptions and actual research is limited. Direct ground water discharge to the Great Lakes and coastal wetlands is poorly known and systematic research to estimate this discharge does not exist. While ground water is recharged everywhere in the watershed, except portions of lakes and streams, some parts of the watershed have much higher rates of recharge than others. These areas need to be systematically identified so appropriate measures can be taken to preserve them.

Recommendation

The Council recommends the following to the IJC.

- **Recommend to the Parties that the highest priority research funding be directed to the following ground water research needs listed in priority order:**
  - **a. research on the effects of land-use changes and population growth on ground water availability and quality;**
  - **b. development on a comprehensive description of the role of ground water in supporting ecological systems;**
  - **c. development of improved estimates that reliably reflect the true level and extent of consumptive use; and**
  - **d. research on ground water discharge to surface water streams and to the Great Lakes, and a systematic estimation of natural recharge areas.**

3.5 UNDERSTANDING THE LONG-TERM IMPACTS OF WATER LEVEL FLUCTUATIONS, DIVERSIONS AND CONSUMPTIVE USES IN THE GREAT LAKES - ST. LAWRENCE RIVER SYSTEM

The management of physical resources is a challenging problem given the complex diversity of interests. Lake level regulation for the sole or balanced benefit of traditional interests, such as the riparian property, hydropower and navigation, has caused unintended adverse impacts on wetlands, plant communities, fisheries and wildlife. Water use and withdrawals from the Great Lakes system can have serious economic and ecosystem impacts that would also be difficult to reverse.

Based on the concerns of the existing interests and the unintended omission of the ecosystem interest in the current regulation plans and water diversion practices, the Council of Great Lakes Research Managers has identified topical issues that require further research, and recommended actions to be implemented by the governments. The research areas recommended for study primarily pertain to Great Lakes water quality. Because of lake regulation, water use and diversions significantly alter water quality and the ecosystem, it is essential to have research topics and priorities that link the water quality and quantity. The research needs are broadly classified as follows.

3.5.1 Effects of Climate Change and Great Lakes Watershed Hydrology

There is a need for obtaining Global Climate Model Scenarios from meteorologists that provide plausible climate scenarios. These are used in generating hydrologic scenarios for testing alternative regulation plans and for the study of long-term impacts on the ecosystem. Methodologies should be developed to forecast water supplies to the lakes for use in testing alternative regulation plans. It is recommended that a system simulation model be developed to include the Great Lakes - St. Lawrence River and downstream tributaries, including the Ottawa River. All natural effects should be taken into account including isostasy, a natural process that impacts lake levels throughout much of the Great Lakes basin. This effect is superimposed on all other causes of lake level change and needs to be accounted for. There is also a need for developing a simulation model to define the pre-project conditions for areas downstream of Lake St. Francis.

3.5.2 Research Needs for Wetlands

There is a general consensus among environmental scientists that the frequency and amplitude of high and low lake levels should be increased to more closely approximate natural conditions and reduce the environmental impacts of regulation. Similar recommendations call for establishing acceptable high and low lake level constraints with more variability in water levels between years. Potential responses of wetland plant communities to increased variability were compared with current regulation plans. This comparison showed some improvement in increasing the area of wetland subjected to both flooding and dewatering conditions and thus increased habitat diversity. Such recommendations from environmental scientists were based on topography of a limited number of actual field sites. The development process for the plan was unable to address the seasonality problem, in which many wetlands remain dewatered during the spring spawning season, because the topography information was not suited to the task. Additional shoreline bathymetry data are needed to provide a broader base for development and testing of alternative regulation plans that better serve to provide diverse habitat in wetlands. The shallow water environment is most susceptible to impacts from water level regulation.

Research indicates that plant communities at elevations not dewatered since the low-level period of 1964 had the lowest species diversity and were dominated by several submersed species. The areas that were alternately flooded and dewatered more frequently were found to be rich in species and had the greatest wetland taxa. Exaggerated wintertime

drawdowns result in springtime water levels that are too low to flood wetlands, reducing fish access to wetlands for spawning in the spring.

Monitoring of wetland sites should be based on the potential for critical spawning habitat for fish, such as northern pike that enter wetlands in early spring, and requires detailed topographic data at wetland sites.

Data needs to be collected to determine the impacts of fluctuating lake levels on plant communities at representative sites around the Great Lakes that are subjected to different flooding and dewatering histories.

3.5.3 Coastal Development Including the Evaluation of Riparian Shore Properties and Dredging

The following actions should be given priority for assessing the long-term impacts of lake level fluctuations on the shoreline.

- The stage-damage relationships used in previous IJC reference studies should be reevaluated based on consideration for storm wave effects and storm damage surveys.
- The Lake Michigan shoreline erosion model should be expanded to include all the lakes.
- Data bases for waves, shoreline classification at one kilometer resolution, and recession rates should be developed for all the lakes.
- Research must be conducted to determine the relationship between water level and erosion, flood potential and wetland delineation.
- The long-term impacts of dredging and disposal of sediments must be determined.

3.5.4 Human Ability to Regulate Water Levels and Assessments of Long-term Impacts of Water Level Fluctuations on Ecosystem Integrity

There is a need for establishing the limits of regulation, for the two lakes that are currently regulated, without any additional control structures in the system. Once a new regulation plan criteria is established and found acceptable by all interested parties, including environmental interests not originally included in the current regulation plans, new upper and lower level limits on Lake Superior and Lake Ontario must be reestablished. Accordingly, the limits of our control of the system must be identified.

Water supplies outside the historical range, including climate change scenarios, need to be analyzed to determine the limits of human ability to influence the system. For this purpose, a tested and calibrated system-wide model for the watershed as described is essential.

3.5.5 Common Databases for Environmental and Shoreline Interests, Water Use and Better Tools to Project Future Uses

There is an essential need for good field survey data, shoreline bathymetry and topography of the Great Lakes - St, Lawrence River system at an increased number of wetland sites. Additionally, data is needed on plant communities, fish accessibility to wetland habitat, shoreline geomorphology, riparian property values, and bluff heights and slope.

Data bases need to be developed for obtaining pertinent information related to demographics, marinas (physical layout, operation of facilities and required drafts), water intakes and shore wells. State-of-the-art data collection techniques, such as airborne laser-survey techniques, geographic positioning systems (GPS) and geographic information systems (GIS) are suggested.

There is an essential need for good field survey data, shoreline bathymetry and topography of the Great Lakes - St, Lawrence River system at an increased number of wetland sites. Additionally, data is needed on plant communities, fish accessibility to wetland habitat, shoreline geomorphology, riparian property values, and bluff heights and slope.

Common data bases would serve a number of analyses including wetlands, fish habitat and plant community, recreation boating, and shoreline erosion and riparian property damage. An inventory of currently available geospatial data and development of a common framework for geospatial data are needed to define the required resolution and extent of data.

This recommendation agrees with 1981, 1985 and 1999 reference studies on diversions and consumptive uses carried out for the International Joint Commission that indicated further research needs in this area. A centralized, binational

database for all diversions, withdrawals and consumptive uses based on a uniform method needs to be developed and maintained. All researchers on Great Lakes water uses could use this dynamic database for cumulative impact assessment.

For example, the Great Lakes Commission is authorized to maintain the Water Use Database Repository without the provision of adequate legal and funding mechanisms. Such databases require continual update and support, and need adequate funding to be retained as a viable resource. The data base repository should be linked to a host of forecast models for different types of water use. Water use forecast models that were used in past studies require revisions based on recent trends in manufacturing, agriculture, economy, demographics and scenarios for climate changes. In the same context, these forecast models should consider the effects of water demand management pressures, such as changes in water pricing strategies. An evaluation model should also be a part of this package to determine the cumulative impacts from economic and environment points of view.

A decision support system providing an effective framework for formulating and implementing water quantity management policies and programs is needed. Such a system must be multi-jurisdictional and socially acceptable with due consideration for present and future demands. It must be flexible enough to accommodate uncertainty, yet rigid enough to yield decisions that are both scientifically sound and legally defensible. Current jurisdictional capabilities for the compilation and analysis of water use data need to be assessed in light of present and anticipated needs.

Any new management regime ultimately developed to exercise decision-making authority will undoubtedly require a more comprehensive, consistent and timely approach to data gathering and analysis within and across all basin jurisdictions.

3.5.6 Recommendation

The Council recommends the following to the IJC.

- **Recommend to the Parties that the following broad areas of research and action be implemented as they pertain to Great Lakes water quality:**

a. **research the effects of climate change and develop a simulation of Great Lakes watershed hydrology;**
b. **develop research needs for wetlands;**
c. **research coastal development including the evaluation of riparian shore properties and impacts of increased dredging;**
d. **research the human ability to regulate water levels and assessments of long-term impacts of water level fluctuations on ecosystem integrity; and**
e. **develop a common database for environmental and shoreline interests, water uses and better tools to project future uses.**

3.6 ALIEN INVASIVE SPECIES RESEARCH

3.6.1 Introduction

There are more than 160 nonindigenous species in the Great Lakes, with more discovered every year. Numerous studies have documented the serious environmental and economic consequences associated with alien invasive species (AIS), also referred to as aquatic nuisance species (ANS), becoming established in the Great Lakes. Although many vectors for transporting AIS have been identified, it is widely agreed that the discharge of ballast water from ships entering the Great Lakes from other regions of the world poses the greatest threat. Many different agencies and organizations have recognized and identified actions that should be taken to address the problem. These include the Department of Fisheries and Oceans Canada Science Directorate, Canadian Coast Guard, Transport Canada Marine Safety, U.S. Coast Guard, IJC's Great Lakes Water Quality Board, Great Lakes Fishery Commission, Great Lakes Panel on Aquatic Nuisance Species, Aquatic Nuisance Species Task Force Ballast Water and Shipping Committee, Great Lakes Commission, Council of Great Lakes Governors, provincial governments, and non-governmental organizations, such as the Northeast-Midwest Institute. There has been significant progress in several areas, however, the majority of research has been focused on ecology, restoration and outreach rather than on establishing standards and preventing new introductions.

The IJC's Great Lakes advisory boards recognize the introduction of AIS as a top priority issue. A great deal of effort has been put forth to monitor activities and target value-added contributions to the process of closing the door on new introductions. Over 22 U.S. and Canadian federal agencies have participated in workshops and meetings, chartered committees and have dedicated resources to address this problem. The Council participated in the November 2000 discussions on ballast water and AIS sponsored by the Great Lakes Water Quality Board in Québec City, Québec and heard further presentations about research needs during its own January 2001 meeting in Windsor.

The Council fully supports the effort put forth by the Water Quality Board to explain current issues, concurs with the board's recommendations for research leading to short- and long-term practical solutions and the need for immediate action. The Water Quality Board's recommendations regarding AIS can be found in section 1.2.

The need for communicating and coordinating AIS research is more important than ever. During the upcoming year, as part of its analysis of overall Great Lakes research and monitoring needs, the Council will review invasive species research needs and funding requirements. The resulting guidance document will provide more concise guidance and sound recommendations to the IJC regarding what the Parties should budget for additional research. The Council will also continue to promote collaboration and effective communications between researchers, agencies and governments though its web-based research inventory database.

3.6.2 Strategic Planning

In a joint report with the Great Lakes Fishery Commission issued in September 1990, the Commissions made the two following specific recommendations regarding research.

- The United States and Canada ensure, in cooperation with shipping and other interests, that a major applied research and development program is established that devises and tests improved measures for the exchange and/or treatment of ballast water.

- The governments of the United States and Canada work together to foster and encourage long-term strategic research on all dimensions of the exotic species problem.

A considerable amount of research is being done on nonindigenous species, particularly in the United States. Current entries in the Council's Research Inventory indicate an annual amount of more than $42 million (U.S.) expended on research studies that include nonindigenous species research since 1999. This represents approximately 13 percent of the total expenditures on research entered into the inventory for that period. Recognizing that participation in the Research Inventory is incomplete, this would represent a low estimate of actual expenditures. A summary of historic funding levels for aquatic nuisance species programs for U.S. agencies can be found on the Northeast-Midwest Institute's web site. It lists budget data for the National Oceanic and Atmospheric Administration, the U.S. Army Corps of Engineers, Department of the Interior, U.S. Coast Guard, and the Environmental Protection Agency. Between 1992 and 2000, more than $80 million (U.S.) was allocated to

Facility deployed through the United Nation's Development Programme, to enable the International Maritime Organization to assist developing countries to tackle the transfer of harmful aquatic organisms in ships' ballast water. This program should be completed in May 2003.

Recent and ongoing studies in the Great Lakes include the Great Lakes Ballast Demonstration Project, the Michigan Department of Environmental Quality project to test the effectiveness of biocides, and the $1.7 million (U.S.) project to sample and assess the threat from ships declaring no ballast on board.

these five agencies for ANS programs. Although this figure includes salary funds, it does not include additional funds provided in the National Sea Grant or Great Lakes Environmental Research Lab budgets from 1996 to 2000 for ANS programs. A May 2001 Great Lakes Panel on Aquatic Nuisance Species report indicates that in 2000, $3.1 million was expended by National Sea Grant with $2.2 million going to research and $0.9 million to outreach programs.

The Uniform National Discharge Standards (UNDS) program for liquid discharges from U.S. military vessels includes ballast water discharge research. In this program, with the U.S. Navy as the lead, 25 discharges were identified that will require marine pollution control devices (MPCDs). The UNDS rule making process aims to establish MPCD performance standards and regulations governing the design, construction, installation and operation of MPCDs. Although interested states have been involved in the UNDS effort since its inception, and the Navy is involved with the Ballast Water and Shipping Committee of the Aquatic Nuisance Species Task Force, this effort has not facilitated establishment of commercial ballast water discharge standards. This appears to be mainly due to assigning ballast water discharge controls a lower priority than other discharges addressed by UNDS. The total cost for research, development, procurement and installation of MPCDs for 169 naval surface ships is estimated to be $318 million. If commercial and military programs were harmonized, these resources could be leveraged to speed development of ballast water control standards to benefit both the commercial and military sectors.

On the international level, as active members of the International Maritime Organization, both Canada and the U.S. will benefit from the results of Global Ballast Water Management program research. This is a three year, $10.2 million (U.S.) initiative using funds from the Global Environment

With this amount of research activity, it has been questioned why the problem has not been solved in more than 10 years. There are three primary reasons:

- the problem is immense and requires a broad spectrum of research;
- there is currently no readily available 'off the shelf' treatment technology providing a suitable alternative to ballast water exchange for all vessel types; and
- there is a tendency toward research into the effects and control of alien invasive species already present in the system rather than toward prevention of new introductions.

The Great Lakes Panel on Aquatic Nuisance Species noted the lack of emphasis on prevention of new introductions in its 1996 policy statement *Research Guidance for the Prevention and Control of Nonindigenous Aquatic Nuisance Species in the Great Lakes*. The Panel reported that 1995 research data indicated, "53 percent of all projects received examined the ecosystem effects of species already present, while only 5 percent of the total expenditure was on prevention of introductions." This percentage has slightly increased over the past six years, but there is plenty of room for improvement. The National Sea Grant College Program report *Aquatic Nuisance Species Report An Update on Sea Grant Research and Outreach Projects 2000* lists 62 projects for FY 1999 and 2000. Of these ANS projects, five list the primary focus as "ballast" and three as "prevention." This represents approximately 13 percent of the total, with 87 percent of the projects focusing on ecology, restoration and outreach.

As the IJC and Great Lakes Fishery Commission did in 1990, the Great Lakes Panel on Aquatic Nuisance Species pressed for a strategic planning effort in 1996, recommend-

ing measures to strengthen the current research infrastructure, both in the U.S. and Canada. These included the following recommendations.

- Develop a national research strategy for nonindigenous aquatic nuisance species that is interjurisdictional in scope and contains three fundamental goals that operate simultaneously: prevention of new introductions; control of already introduced species and restoration of the aquatic ecosystem; and recognize research needs identified in state management plans for aquatic nuisance species.

- Develop an overarching coordinated action plan or regional policy agreement, including short- and long-term agendas, to ensure commitment to collective multi-jurisdictional action on ANS prevention and control. This may include commitment for interjurisdictional cooperation in prevention and control; development of consistent state and provincial laws and programs; sharpened delineation between agency roles and responsibilities; establishment of a regional emergency response team; and establishment of a center for invasive species control.

In its *Eighth Biennial Report on Great Lakes Water Quality* published in June 1996, the IJC again emphasized the need for a strategic approach stating, "A basinwide, binational strategy should be developed to prevent further introductions by any route of potentially harmful species."

Responding to this need, the U.S. and Canadian governments commissioned a study by the National Research Council Marine Board of the National Academy of Sciences, which published its report *Stemming the Tide* in July 1996. Based on recommendations from the marine board, the two governments set forth a binational research strategy and was included in their binational *1996-1997 Report on Great Lakes Water Quality* by the Department of Fisheries and Oceans Canada Science Directorate, Canadian Coast Guard, Transport Canada Marine Safety and U.S. Coast Guard. This report recognized the importance of near-term treatment options for vessels with no ballast on board (NOBOB). It also addressed urgent requirements to review the safety of ballast exchange in current ship designs and to develop practical measures for confirming exchange in addition to measuring salinity. This strategy was developed by U.S. and Canadian federal agencies, taking into account the associated work being sponsored by the Great Lakes Protection Fund, the Michigan Office of the Great Lakes and other agencies around the world. In addition, the report stated that the agencies would facilitate studies of filtration included in the Great Lakes Ballast Water Demonstration Project, and the Canadian Department of Fisheries and Oceans and Michigan Department of Environmental Quality studies of certain biocides. Research in these areas has been funded and is underway.

The *1996-1997 Report on Great Lakes Water Quality* by the Department of Fisheries and Oceans Canada Science Directorate, Canadian Coast Guard, Transport Canada Marine Safety and U.S. Coast Guard . . . recognized the importance of near-term treatment options for vessels with no ballast on board (NOBOB). It also addressed urgent requirements to review the safety of ballast exchange in current ship designs and to develop practical measures for confirming exchange in addition to measuring salinity.

Several other documents have been published to provide direction to research programs. The Great Lakes Panel on Aquatic Nuisance Species made sound recommendations in 1996 and again in 1998 on research needs and how to strengthen the research infrastructure both in the U.S. and Canada. In March 2001, they published the Great Lakes Ballast Water Management Policy Statement. This plan also represents a strategic, binational effort that sets goals and identifies short- and long-term research needs.

How much will additional research cost? This question has not been fully answered. The Great Lakes Commission identified over $37 million (U.S.) in funding requirements for AIS in its draft report *The Great Lakes Program to Ensure Environmental and Economic Prosperity - Great Lakes Commission Priorities to "Restore the Greatness."* This report recommended over $10 million annually for ballast technology development and demonstrations, however more specific requirements must be identified and prioritized.

3.6.3 Research and Monitoring Needs and Priorities

The U.S. Coast Guard noted the absence of sufficient applied research in several key areas in a Federal Register notice dated April 2001, in particular the lack of data on the effectiveness of ballast water exchange (BWE):

"Currently, the actual "effectiveness" of BWE is not well resolved ... The more finely resolved approach based on effectiveness profiles across taxonomic groups for major types

of vessels would require an as yet undeveloped data set on BWE effectiveness across major ship classes and biotic groups. This approach would require a focused research effort to identify the data gaps and conduct the necessary experiments ... Standards based on the capabilities of the best available technology will also require a significant amount of additional work, as most existing systems are still in preliminary phases of development. Significantly, for standards based on either BWE or best available technology, important decisions will need to be made concerning the specifics of standardized testing protocols."

A summary of research recommendations from the Department of Fisheries and Oceans Canada Science Directorate, Canadian Coast Guard, Transport Canada Marine Safety and U.S. Coast Guard, the Great Lakes Regional Panel on Aquatic Nuisance Species, the Northeast-Midwest Institute, and the Great Lakes Commission is found in Appendix 1. These recommendations indicate many areas of common concern, notably in the areas of standards development and prevention.

Recommendations

The Council recommends the following to the IJC.

- **Recommend that the Parties place an emphasis on the immediate implementation of current AIS research recommendations proposed by the Great Lakes Water Quality Board and other advisory panels.**

- **Recommend that the Parties give priority support and funding to well-focused, applied research needed to establish ballast water discharge standards and prevent new introductions of AIS.**

- **Recommend that the Parties provide resources for a binational coordination of efforts to ensure that a mutually acceptable ballast water discharge standard is developed and that unnecessary duplication of efforts is eliminated.**

During the coming year, the Council's Research and Monitoring Needs and Priorities subcommittee will further examine current research recommendations and look at studies in progress in order to identify funding requirements. In this way, the Council can provide recommendations to the IJC regarding the total commitment of funding they should seek from Canada and the United States to fill critical research gaps and eliminate the threat of new introductions of alien invasive species.

3.7 FRAMEWORKS FOR MODELLING ECOLOGICAL CHANGE IN THE DETROIT RIVER - LAKE ERIE CORRIDOR

Background

In 1997, the Lake Erie Task Force recommended that the Council of Great Lakes Research Managers bring together modelers and resource managers to address the development of a model for Lake Erie. Based on this recommendation, the Council hosted the *Great Lakes Modelling Summit: Focus on Lake Erie*, March 27-28, 1999 during the International Association of Great Lakes Research conference at Case Western Reserve University in Cleveland, Ohio. This workshop examined the feasibility of building an aquatic ecosystem model for Lake Erie that could examine the ecosystem-level effects of multiple stressors acting in concert.

Workshop

Building on this work, the Council hosted another modelling workshop to coincide with the *Lake Erie in the Millennium- Progress and New Issues* binational conference held March 28-29, 2001. This workshop built on the previous modelling summit, but focussed on the western basin of Lake Erie and more specifically on the Detroit River - Lake Erie system.

First, a roundtable discussion was conducted on *The Influence of the Detroit River on the Lake Erie Ecosystem.* Participants identified key features and tests necessary to evaluate the question, "What is the likely role of Detroit River remediation on the Lake Erie ecosystem?"

During the afternoon, the Council held a modelling workshop titled *Frameworks for Modelling Ecological Change in the Detroit River – Lake Erie Corridor.* This workshop provided modelers with an opportunity to comment on how well the measurements and experimental proposals made during the roundtable session would fit into a modelling framework. The proceedings provided background on previous efforts and took note of important observations made at *The 2001 Lake Erie in the Millennium* conference.

An example of the discussion included, in particular, the fact that total phosphorus levels in the lake appear to be going up and whether this observation is the result of increased loadings of phosphorus to the lake or of changes in in-lake processing of phosphorus loads. It was noted that the future challenge for modelers is to take observations, such as phosphorus concentration trends, and convert them into quantitative hypotheses that can be tested within a modelling framework. Informed decisions could then be made on what should be done and what priorities should be made in order to improve the system.

It was noted that the initial question, "What is the likely role of Detroit River remediation on the Lake Erie ecosystem?" is a very generic management question. Using a model to address this question requires modelers to become more specific and address questions such as the following.

If we want to remediate the Detroit River so as to improve Lake Erie as well:

- Where should we focus?
- Where should we start?
- Where should we spend our money?
- How can specific potential remediation alternatives be simulated within a modelling framework?

The point was made that as research tools, models are an integral part of the scientific method. It was stated that:

"Models serve as a means of quantitatively synthesizing process experimental results and theory along with field observations into a whole system hypothesis-testing tool. With complex ecosystems, it becomes virtually impossible to measure ecosystem structure and functioning at the scale necessary to test hypotheses strictly with data; this is where system-level models have great value. While we can never really simulate the entire ecosystem, we can mathematically reproduce our conceptual model of the key processes and feedback as a means of testing system response to conditions that may exist but for which we do not have empirical experience. The great value of models used in this research mode is the knowledge gained when they "fail". In this way gaps in our data or understanding are indicated. Then we can iterate between monitoring/experimentation and model application in order to build our understanding of how the ecosystem responds to external stimuli.

The challenge of course, is establishing a management model and a research model in the single framework. Often, the demands for spatial and temporal and kinetic (or process) resolution in a research model may be very different than a management model. For example, a management model for PCB's might just look at total PCB's. However, this is generally not appropriate for a research study. For research purposes, we might want to look at the behavior of some of the PCB congeners individually. These things make it a

challenge to address both a management and a research model question in the same program."

The following specific modelling questions were addressed and related to the overall theme of modelling ecological change in the Detroit River – Lake Erie corridor:

- What types of models and approaches are most appropriate to complement the suite of measurements previously proposed?
- Can one model address all of the issues of concern? If multiple approaches are warranted, which ones best fills the gaps?
- What important compartments and state variables may have been omitted?
- Is the proposed geographic extent of sampling sufficient?
- Will the proposed measurements generate the types of data sufficient to create a mass budget or mass balance model?
- What temporal and spatial resolution of sampling is appropriate and what time frame should be considered?
- Can the physical and biological processes be sufficiently integrated?
- What resources, such as monetary or collaborative would be necessary to undertake a suitably sensitive and general model?

The cost of modelling is relatively small portion, 10-12 percent, of the total project cost compared to other remediation project costs and can ensure the quality assurance of remediation.

Conclusions and recommendations from the workshop are as follows.

- **Models need to test a hypothesis that incorporates both a research and management need.**
- **Toxicokinetic models need to be coupled with hydrology models by using appropriate technologies such as a geographic information system (GIS).**
- **Modelers need to incorporate people and human influences into their models.**
- **Demographics will influence the direction of Great Lakes research in the future including loss of expertise and lack of recruitment of Great Lakes researchers.**
- **Current monitoring in the Detroit River is insufficient to develop appropriate models that can make predictions or merely explain current state of the Detroit River- Lake Erie system.**
- **A loss of representative sampling in the Detroit River, 'sampling erosion,' has resulted in biased data.**
- **The system needs to be considered as a corridor, including the area from the head of the St. Clair River, Lake St. Clair, Detroit River and Lake Erie.**
- **Sharing data and models with the public can create advocacy for models.**
- **Upstream and downstream monitoring, appropriate detection limits and up-to-date intensive monitoring to develop loadings should be reinstated.**
- **The cost of modelling is relatively small portion, 10-12 percent, of the total project cost compared to other remediation project costs and can ensure the quality assurance of remediation.**
- **Peer review and validation of models is important and a 'battle of the models' would help to review and critique proposed models for the corridor.**

The full transcript of workshop proceedings will be published as a separate document and made available on the Council's web page. http://www.ijc.org/boards/cglr

3.8 ONGOING INITIATIVES AND NEW ACTIVITIES

3.8.1 The Great Lakes - St. Lawrence Research Inventory

The Great Lakes - St. Lawrence Research Inventory is an important tool for the Council of Great Lakes Research Managers to gauge research activity in the region. The Research Inventory is an Internet-based, searchable database that collects and disseminates information on research programs relevant to the Great Lakes Water Quality Agreement. Since 1985, the Council has continuously gathered descriptions of research programs from its members, as well as from external agencies and institutions. Previous to the Council's efforts to track Great Lakes research, the Research Advisory Board, which became known in 1979 as the Great Lakes Science Advisory Board, conducted research reviews in 1975, 1976, 1978 and 1982. In 1995, the Council took advantage of the Internet to extend its data collection efforts and increase the consistency and availability of this information through the web. The inventory allows Great Lakes researchers to identify similar studies, network, share experiences and increase efficiency. It also enables the Council to examine the impact and adequacy of research as stipulated by the Agreement, to reveal the interrelationships between research disciplines and to link research to policy questions. The Council hopes to promote the transfer of information on research programs to basin policymakers, resource managers and the public.

The inventory currently has 650 projects listed representing approximately $140 million U.S. ($214 Million CDN) in research expenditures and is accessed between 200 and 300 times per month. During this priority cycle, the Council took steps to improve data analysis capability and to capture data on environmental economics research studies. The Council is also pursuing improvements to inventory usability to speed updates, incorporate on-line queries and interactive features, simplify database maintenance, automate updates and provide faster access to key information for on-line users.

3.8.2 Science Vessel Coordination

The Fifth Annual Great Lakes Science Vessel Coordination Workshop, sponsored by the Council, was held in Windsor, Ontario, January 22-23, 2001. The workshop produced a strong turnout from both science vessel operators and managers and provided a productive exchange of views and helped promote enhanced communication, cooperation and the more efficient and cost effective use of the Great Lakes science vessel resources.

Breakout sessions were held with three primary groups, the Scientist and Managers, Upper Lakes, and Lower Lakes committees. Institutional and administrative requirements, program development and coordination, advocacy and coalition building, and communications and information sharing were discussed.

Recommendations from this meeting include:

- sharing of shipyard experiences and developing a list of preferred shipyards;
- development of a Great Lakes science vessel brochure to recognize current coordination efforts and to promote greater awareness of this initiative among scientists and the public;
- completion of a staffing survey to compile vessel manning data; and
- incorporation of data regarding laboratory equipment and services into the Research Vessel Inventory.

In addition to this effort, the Council funded an update to the Research Vessel Inventory to better organize data and to provide for improved links to individual vessel web sites. More information on the Research Vessel Inventory is available on the Internet. http://www.buffalostate.edu/~csboats/index.htm

3.8.3 Integrated Great Lakes Observation and Monitoring

In its *Tenth Biennial Report on Great Lakes Water Quality*, the IJC recommended that the Parties develop and implement a binational information policy employing advanced technology to support implementation of the Great Lakes Water Quality Agreement. This followed recommendations from the Great Lakes Science Advisory Board in the *1997-1999 Priorities and Progress under the Great Lakes Water Quality Agreement* report on a coupled Great Lakes Observation and Modelling System.

Based on these recommendation and a 1998 U.S. national program for Sea Floor Observatories established by the White House as a Presidential Initiative to be implemented through the National Undersea Research Program of NOAA; the Council studied the concept of developing the Great Lakes into 'instrumented ecosystems' where fish and zooplankton

populations are tracked, 3-dimensional current structures mapped, and *in situ* chemical and physical analyzers, optical systems and biomonitoring systems gather real time data via remote monitoring (V. Klump). In 2000, the National Research Council set out a plan to approach the problem and recommended that the National Science Foundation build ocean observatories. The report, *Illuminating the Hidden Planet the Future of Seafloor Observatory Science*, by the Committee on Seafloor Observatories's Ocean Studies Board, includes many well-supported findings and recommendations. This report is available on the Internet. http://books.nap.edu/books/0309070767/html/R1.html

The Great Lakes Science Advisory Board and the Council formed a joint subcommittee in 2001 to sponsor a workshop exploring the potential of the Great Lakes basin as a pilot area for initial testing and deployment of this technology. This workshop is scheduled for Fall 2001 and will lay the foundation for further plans and recommendations to the IJC on this important new initiative.

3.8.4 Emergence of New Pathogens

The serious risks posed by aquatic invasive species are much better understood than the risks posed by the introduction of viruses, bacteria and protozoans. Infectious agents, capable of causing illness in humans or animals, are commonly referred to as pathogens and considered in a separate category from nonindigenous species. Researchers in the Chesapeake Bay area have measured an average of approximately 2 million bacteria and twenty million viruses per milliliter of ballast water from ships entering that waterway. Similar measures may be expected from samples taken from ships entering the Great Lakes system. It is estimated that between 500 to 600 foreign flag vessels enter the Great Lakes each year. Seaway-size bulk carriers have a ballast capacity of about 20-40 percent of the weight of the cargo, typically from 2 to 4 million gallons (7.6 to 15.2 billion milliliters) of ballast water. Consequently the number of microorganisms delivered to the Great Lakes basin in ballast water is astronomical. The majority of these microorganisms are not pathogenic and occur naturally in aquatic ecosystems, however the environmental risks associated with global transport of ballast water microbes are not well understood.

A number of pathogens in Great Lakes waters have been identified over the past decade, including cryptosporidia, giardia, cyclospora and E. coli. Another pathogen that is always of potential concern is cholera, ever-present in waters elsewhere in the world.

At the present time, the full impact on human health from some of these pathogens has been only explored as it relates to isolated outbreaks. Typically, little is known about their long-term presence, viability and impact on other Great Lakes organisms and ecosystems. Further examination of these issues to better understand and predict their implications, as pertains to the Great Lakes waters, may be warranted in upcoming meetings and symposia. Accordingly, this topic was identified as an emerging issue of concern and the Council plans to scope out this issue in detail during the upcoming priority cycle.

3.8.5 Research and Monitoring Needs and Priorities

At its January 2001 meeting, the Council formed a subcommittee on Research and Monitoring Needs and Priorities. The Council believes that the Great Lakes 'family' of agencies should help the regions elected officials articulate the needs of the basin more effectively to secure funding to solve the many problems facing the region. Many have taken note of the funds recently appropriated by the U.S. Congress for restoration of the Florida Everglades and cleanup of the Chesapeake Bay. All agree that the problems facing the Great Lakes region are equally challenging and deserve the same level of support. The Council agreed that the Florida Everglades model is a good one, but is focused primarily through one agency. The Chesapeake Bay model is also good, but it is focused primarily on one issue -- eutrophication. In the Great Lakes, the challenge is to reach consensus amongst many agencies and many issues.

The Council's charge to this committee is to go beyond the identification of emerging issues and to identify research and monitoring needs and their associated funding requirements. This will enable the Council to provide sound advice to the IJC on what level of funding is really needed for the governments to address these problems. The Council has invited members of the Science Advisory Board and the Water Quality Board to participate on the subcommittee so that a strong consensus may be forged. A report on priorities and funding requirements is to be provided before the end of 2001.

3.9 COUNCIL MEMBERSHIP FOR 1999 - 2001

United States Members

Dr. Stephen B. Brandt, Co-Chair
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Appendix I. Summary of Recommendations Regarding Research Needs Associated with Non-indigenous Invasive Species Control Measures

1996-1997 DEPARTMENT OF FISHERIES AND OCEANS CANADA SCIENCE DIRECTORATE, CANADIAN COAST GUARD, TRANSPORT CANADA MARINE SAFETY, AND THE U.S. COAST GUARD BINATIONAL PLAN

Source: 1996-1997 Report on Great Lakes Water Quality by Department of Fisheries and Oceans Canada Science Directorate, Canadian Coast Guard, Transport Canada Marine Safety, and the U.S. Coast Guard.

(242) The Binational Plan to Support the Comprehensive Research Strategy

The purpose of the plan, quite simply, is to fill in those critical elements of the overall strategy which are not being adequately addressed at the present time, within the limits of the competence, funding, and political direction of the agencies, taking advantage of opportunities for collaboration with other agencies and organizations also doing work on these issues.

(242.1) Specific Projects to be Developed by the Agencies

Based on a review of the work in progress and the outstanding issues which need to lie addressed as soon as possible, the agencies have agreed to pursue the following priority projects.

- Evaluation of Exchange. Within this general project, two critical issues need to be addressed:

- Review of the safety of pump-down exchanges, specifically their effect on hull integrity and ship stability, for all relevant classes of vessels, including both large vessels calling at North American saltwater ports, and smaller but narrower vessels entering the St. Lawrence Seaway. This subproject should include historical comparisons of hull cracking in Seaway vessels in order to attempt to distinguish hull cracks which may be caused by pump-down exchanges since the beginning of the Great Lakes regime and hull cracking which is caused by other factors (design, age, loading practices). Because of the initial study already conducted by the Canadians, this subproject is an excellent candidate for formal US/ Canadian collaboration.

- Development of tests and protocols for confirming exchange, beyond the current salinity tests used in the Great Lakes. Two types of tests are needed (and both are likely to be an important part of any North American or worldwide regime). 1. A relatively simple and real-time field test, which can be used on board a vessel by both the vessel operators and the government agencies, to provide a reasonable indication that an adequate exchange has been conducted before a vessel enters port or discharges ballast. 2. A scientifically reliable and legally enforceable test, which may well not be real-time, to allow both scientific validation of any regime and punitive enforcement action against violators of a mandatory regime.

- Near-Term Captions for NOBOB. Prompt action is needed to deal with the problems presented by the NOBOB, which constitute a significant gap in both the Great Lakes regime and any national or world-wide regime. Within this general project there are three SUBPROJECT which are most likely to lead to solutions in the near future.

- Better evaluation of the threat posed by the slop and sediment in the bottom of the NOBOB, specifically including evaluation of the practicality and effectiveness of short-term operational measures such as the "partial exchange" or "swish and spit" in controlling the organisms in the slop and sediment. Because of the initial testing already conducted by the Canadians, this subproject is an excellent candidate for formal US/ Canadian collaboration.

- Hydrodynamic modelling of feasible tank retrofits making it possible to conduct flow-through exchanges, specifically including retrofits which would make it possible to conduct top-down flow-through exchanges on NOBOB. This subproject would address both the NOBOB problem and the problem of safety constraints on pump-down exchanges on all vessels.

- Tests of the feasibility and effectiveness of heating the slop and sediment on NOBOB, which may be practical through simple shoreline injections of heated water due to the relatively small quantities of water involved.

Because of the initial study already conducted by the Canadians, this subproject is an excellent candidate for formal US/Canadian collaboration.

- Realistic cost comparisons of the competing options. We need rigorous, credible, and consistent economic analysis of the competing options, including filtering, follow-on treatments associated with filtering such as UV, heat in its various modes, plausible biocides, and various configurations for tank retrofitting and redesigns. This economic analysis is essential to the development of any real-world regulatory regime.

(242.2) Other Projects Supported by the Agencies

The specific projects listed above are the critical needs which are not being currently addressed by other projects, which are within the current funding guidance to the US Coast Guard, and which allow for some formal collaboration with the Canadian agencies. In addition, the agencies will offer whatever support they can to other work taking place in the Great Lakes region:

- The Great Lakes Ballast Demonstration Project, which is studying filtering, and has now, expanded to study pathogens in ballast water, (See Appendix I.) This project has already received some funding from the US Coast Guard, and significant funding from the Great Lakes Protection Fund. At this time, the US Coast Guard is actively assisting that project in taking samples from foreign vessels in Messina.

- DFO and Michigan Office of the Great Lakes studies of certain biocides. Within the limits of the funding guidance to the US Coast Guard, which is restricted in this respect, the agencies will work together to facilitate any intergovernmental approvals and held tests which may be appropriate to test the effectiveness and environmental acceptability of limited applications of biocides in NOBOB vessels entering the Great Lakes.

GREAT LAKES PANEL ON
AQUATIC NUISANCE SPECIES

Source: Policy Position of the Great Lakes Panel on Aquatic Nuisance Species, Research Guidance for the Prevention and Control of Nonindigenous Aquatic Nuisance Species in the Great Lakes. Adopted December 4, 1996.

1996 Recommendations

Recommendations on ANS research gaps and needs have been classified by six research categories adopted by the Great Lakes Panel on Aquatic Nuisance Species as well as the national ANS Task Force.

Biology and Life History

- Perform a timely literature review and translation of information on all newly introduced species to eliminate duplication of research.
- Determine and prepare potential range maps for all new introduced species in a region.
- Prepare risk assessments to determine impacts on native species.
- Study genetic characterization of invaders and source populations.

Control and Mitigation

- Increase education and research activities for alternate control options and eradication of aquatic nuisance species.
- Develop a model plan for eradication of a nonindigenous aquatic nuisance species that outlines the necessary procedures to be undertaken in the event of a new invasion.
- Improve documentation and transfer of private sector research.
- Enhance bioengineering of species-specific pathogens.
- Develop and examine containment options for species already present.
- Explore the technical feasibility of integrated pest management (I'M). I'M integrates various control measures and examines the economic benefits versus costs in determining whether control is beneficial.

Ecosystem Effects

- Enhance/maintain monitoring programs to establish pre-invasion data on native species and to provide a better understanding of the community structure in the Great Lakes region. This will allow for more informed decision making on potential control options in the

event of an invasion of a nonindigenous aquatic nuisance species.

- Determine the ecosystem response (environmental and social) to the control/containment of nonindigenous aquatic nuisance species.
- Develop the theory of ecosystem resilience toward the establishment and dominance of nonindigenous aquatic nuisance species.
- Develop more reliable ecosystem models to assist management in making decisions on mitigation of impacts or on the control of established nonindigenous aquatic nuisance species, if control is possible.

Prevention of Introductions

- Identify, understand and perform risk assessments of pathways, next likely invaders (including pathogens), and likely sources of origin for new invasions.
- Identify maritime transportation routes that have demonstrated or have the potential capability to advance the spread of aquatic nuisance species. Develop and evaluate prevention and control options, including exploring ballast water management technologies.
- Examine current legislation regulating the importation of nonindigenous aquatic nuisance species to ensure proper prevention and control measures are in place (e.g., aquarium and pet trade industry, aquaculture).

Socioeconomic Considerations and Analysis

- Estimate the economic costs of current and historical damage (physical, biological, industrial, recreational, ecosystem) to the Great Lakes caused by the invasion of nonindigenous aquatic nuisance species.
- Estimate the costs and benefits (economic and social) of adopting new prevention and control technologies, including an examination of ways to minimize these costs to the affected industry.
- Utilize the concept of biological pollution when referring to the introduction of nonindigenous aquatic nuisance 4 species.

Spread of ANS Populations

- Identify, understand and perform risk assessments of potential dispersal pathways within the Great Lakes region.
- Monitor and review federal, state and provincial laws and regulations to ensure that prevention and control measures address all pathways of concern (e.g., aquaculture, aquarium, pet trade) in a consistent manner from one jurisdiction to the next. Gaps and inconsistencies should be resolved accordingly.
- Prepare potential range maps for species already present.
- Institute programs in the U.S. and Canada for early detection and reporting with incentives for participation.
- Require containment guidelines for all research projects handling aquatic nuisance species (public and private sector research).
- Examine dispersal barriers i.e., choke points to control the spread of established populations (e.g., Chicago River).

Strengthening the Research Infrastructure

- Develop a national research strategy for nonindigenous aquatic nuisance species that is interjurisdictional in scope and contains three fundamental goals that operate simultaneously: prevention of new introductions, control of already introduced species, and restoration of the aquatic ecosystem as well as recognize research needs identified in state management plans for aquatic nuisance species.
- Develop an overarching coordinated action plan or regional policy agreement (with short and long-term agendas) to ensure commitment to collective multi-jurisdictional action on ANS prevention and control. This may include commitment for interjurisdictional cooperation in prevention and control; development of consistent state/provincial laws and programs; sharpened delineation between agency roles and responsibilities; establishment of a regional emergency response team; and establishment of a center for invasive species control.
- Develop and institute pre-clearance regulations for the importation of aquatic shipments (fish, plants). This would ensure that cargo is inspected for nonindigenous aquatic nuisance species before it leaves its destination.
- Increase interest/concern about other less highly publicized species by designating them as aquatic nuisance species or by identifying them as regional priorities for prevention and control.
- Institute a national program for early detection and reporting with incentives for participation.
- Develop and link ANS research databases nationally and internationally on the Internet to foster better communication among researchers.
- Enhance communication on ANS issues between scientists and Sea Grant agents as well as the general public.
- Continue research on ANS by reauthorizing the federal Nonindigenous Aquatic Nuisance Prevention and Control Act (National Invasive Species Act of 1996) and adequately appropriating funds. Research priorities should reflect the recommendations of the national ANS Task Force and/or the Great Lakes Panel on Aquatic Nuisance Species and other relevant organizations.

1998 Recommendations

Source: Policy Position of the Great Lakes Panel on Aquatic Nuisance Species. A Binational Canadian-United States Ballast Water Research Strategy. Adopted February 1998.

To advance implementation of its December 1996 policy position, the Great Lakes Panel on Aquatic Nuisance Species recommends that its member agencies and organizations support the following research action plan.

- **Evaluation of Exchange**
  - Review the two technical reports on the safety of ballast pump-down exchanges for all relevant classes of vessels, including both large vessels calling at North American saltwater ports, and smaller but narrower vessels entering the St. Lawrence Seaway. Perform studies to determine hull stress, bending moment, seakeeping characteristics and overall safety of exchange. Evaluate potential increase in fatigue cycles to hull components due to additional ballast exchanges at sea.
  - Develop and support ongoing efforts to develop field-type tests and protocols that confirm that ballast exchange has taken place at sea. Two types of tests should be considered, including: 1. A simple and real-time field test to be used on board a vessel by both the operators and applicable government agencies. 2. A scientifically reliable and enforceable test to allow both scientific validation and enforcement action.

- **Evaluate Near-Term Options for NOBOB Vessels**
  - Evaluate the threat posed by slop and sediment in the bottom of NOBOB as well as the practicality and effectiveness of short-term operational measures such as "partial exchange," or a "swish and spit," in controlling organisms in the slop and sediment. Support demonstration projects to validate these and other relevant methods.
  - Conduct modelling to evaluate flow-through methods (top-down and bottom-up) for effectiveness of water and sediment displacement and potential biological effectiveness. Evaluate the costs of retrofitting existing systems for the two alternatives as well as the costs of incorporating changes into new ships at the design stage. Support demonstration projects of the alternatives to validate results.
  - Support studies for shipboard heating or shoreline heating of smaller quantities of water and "hot shotting" individual tanks. Provide realistic refit costs for both shoreline and shipboard systems and provide realistic vessel delay times to perform the operation ashore.

- Biocide Studies Relevant U.S. and Canadian agencies and organizations should work together to assure efficient consideration of permit applications for field tests of potential biocide treatments for ballast residuals. Studies must demonstrate that candidate chemicals can be stored and disposed of in an environmentally sound manner and break down into environmentally sound, harmless byproducts before any discharge into the Great Lakes.
- Support of Ongoing Research U.S. and Canadian agencies and organizations are encouraged to support and participate in initiatives (e.g., Great Lakes Ballast Demonstration Project, and Canadian Dept. of Fisheries and Oceans and Michigan Office of the Great Lakes biocide research) that examine specific approaches to ballast water management or critical, associated needs.

March 2001 Recommendations

Source: March 2001 Great Lakes Panel on Aquatic Nuisance Species Policy Statement on Ballast Water Management.

Technology Options and Research Needs

- Evaluate ballast water management practices and treatment technologies, including ballast water exchange, in terms of crew safety, effectiveness, real-world technical viability, environmental acceptability, economic feasibility, practicality and enforceability.
- Evaluate how vessel structure, age, operating conditions, crew capabilities and other factors affect ballast water technologies and management approaches.
- Consider the use and effectiveness of combinations of ballast water treatments.
- Assess the effectiveness of best management practices and non-chemical treatment methods (e.g., ultraviolet treatment) for ballast water management.
- Develop protocols for the use of biocides as a treatment option for ballast management, particularly in regard to NOBOB, and evaluate their use in terms of environmental implications; effectiveness; physical effects on vessels; health and safety risks; and consistency with the stated policies of federal, state, provincial and regional Great Lakes-St. Lawrence entities.
- Evaluate the potential of shore-based ballast water treatment facilities at critical chokepoints in the Great Lakes-St. Lawrence system as one component of a ballast water management program.
- Implement full-scale application on commercial vessels of promising ballast water management/treatment technologies that have shown potential in demonstration projects to minimize ANS discharges.
- Develop and implement a ballast water sampling program using water quality and/or biological criteria as benchmarks to measure improvements that occur with various treatment methods.

Research Funding and Coordination

- Establish secure, dedicated, long-term, federal funding that will provide sufficient support for research, ballast water sampling and monitoring, and demonstration projects for ballast water management practices and technologies.
- Develop and utilize mechanisms to expedite sharing and widespread dissemination of results, such as a single Internet site, that cross-links research topics with projects, researchers and funding organizations.

Management of NOBOB

- Evaluate the potential for NOBOB to introduce and spread ANS and assess the economic and environmental risks such introductions pose. Include in this evaluation identification of all life stages of organisms, including resting stages and cysts, that are present in NOBOB.
- Determine the utility, environmental implications and desired duration of short-term management approaches to NOBOB, including partial exchange, best management practices, and physical and chemical treatment.
- Evaluate, in conjunction with the marine industry and federal authorities, long-term approaches including technological alternatives, new ship design and other management options that address the ANS problems associated with NOBOB.

Estimation of Costs and Economic Impacts

- Evaluate the costs of retrofitting existing vessels and incorporating ballast water treatment technologies into new vessels.
- Compare the potential environmental impacts and economic costs of ANS invasions against the cost of development and implementation of ballast water treatment measures.
- As promising management options/technologies are identified by research, assess the potential implementation costs to guide development at the full-scale level.
- Examine the potential to modify trade patterns of lakers and ocean going vessels in the Great Lakes-St. Lawrence system to minimize the discharge of foreign ballast. Evaluate the potential economic impacts of ballast water measures in terms of varying vessel types, types of commodities and volume, differing ballasting systems and alternative transportation modes.
- Examine the economic impacts of requiring all ships to stop at a certain point for ballast water treatment (e.g., shoreline treatment).
- Identify and evaluate options to mitigate the financial burden of ballast water management requirements for the shipping industry (e.g., tax credits, federal funding).

Assessment of Human, Fish and Wildlife Health Risks from Pathogens

- Assess the nature and scope of the public health risks posed by potential ballast water pathogens.
- Conduct a fish and wildlife pathogen risk assessment to expand knowledge of this issue.
- Assess the nature and scope of public health risks already present in the waters of the Great Lakes-St. Lawrence system as a framework by which to compare/assess shipborne risks.

NORTHEAST-MIDWEST INSTITUTE

Source: January 23, 2001 Presentation by Allegra A. Cangelosi to Council of Great Lakes Research Managers: *Characterizing Biological Effectiveness of Ballast Water Treatment: Options and Case Examples.*

General Conclusion

"We Should Design Early Research on Ballast Treatments Collaboratively to Determine Meaningful Evaluation Benchmarks and Treatment Objectives."

Conclusions

- Bioeffectiveness of treatment technologies is influenced by properties of organisms (e.g. morphology and regrowth potential), water (physical/chemical), and ships (operational/structural).
- Each technology will have strengths and limitations relative to critical parameters.
- Early studies should help define critical parameters and overall treatment objectives, so that later studies can efficiently "profile" bioeffectiveness of proposed treatments.

General Issues for Collaborative Investigation

- What should our treatment objectives be, especially with respect to microbes?
- At what scale (and for which organisms) do pilot research findings become predictive of shipboard performance?
- Will operative morphological/physical/ chemical features in one geographic region predict treatment effectiveness on organisms of another assemblage/ geographic region?

A Common Metric?

- How do we measure success (mortality vs. inactivation, percent reduction vs. absolute concentrations)?
- How do we incorporate retention effects (e.g. die-off, regrowth)?
- How do we predict the fate of moribund plankton once discharged into the receiving system?

GREAT LAKES COMMISSION

Great Lakes Commission Priorities to "Restore the Greatness" (Working Draft) (Posted on GLC web page March 2001).

Selected Priority Actions

- Reauthorization of the National Invasive Species Act (NISA): to strengthen national and regional programs and develop ballast management standards and regulations consistent with recommendations of the Great Lakes Commission and the Great Lakes Panel on Aquatic Nuisance Species.
- Implement Comprehensive State Management Plans (NISA, Sect. 1204): to partner with Great Lakes states on critically important prevention and control programs — $5.0 million annually to the Great Lakes states through the U.S. Fish and Wildlife Service.
- Support the Great Lakes Panel on Aquatic Nuisances Species (NISA, Sect. 1203): to ensure effective, efficient and well coordinated regional prevention and control programs — $0.3 million annually to the Great Lakes Commission through the U.S. Fish and Wildlife Service.
- Ballast technology development and demonstrations: to address a leading vector for invasive species (commercial vessels in ballast or "no ballast on board" status) — $3.0 million annually for each of several federal agencies/facilities with special expertise: Great Lakes Environmental Research Laboratory (National Oceanic and Atmospheric Administration), Great Lakes Science Center (United States Geological Survey), and Great Lakes Sea Grant Program (through the National Sea Grant Program); and $1.2 million annually to the U.S. Coast Guard
- Public facility research and development: to complete the design, construction and evaluation of a dispersal barrier in the Chicago Sanitary and Ship Canal, and undertake related control activities — $3.0 million annually to the U.S. Army Corps of Engineers.
- Sea lamprey barriers: to dramatically reduce infestations with an emphasis on nonchemical alternatives — $3.0 million annually to the U.S. Army Corps of Engineers.
- Best Available Technology on commercial vessels: to secure authorizing language for a program to support retrofitting of commercial vessels to eliminate/reduce infestations and spread — $25.0 million annually to the U.S. Coast Guard.

1999-2001
Priorities Report
Chapter 4

The International Air Quality Advisory Board

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4.1 INTRODUCTION

The International Joint Commission (IJC) and its advisory boards have made major contributions during the past two decades to the understanding of atmospheric deposition of persistent toxic substances. Recently, they have focussed their efforts on the application of transport and deposition modelling for the identification of sources with emissions that must be reduced if Great Lakes water quality goals are to be met. Significant sources lie within and outside the basin and are a mix of large discrete point sources, such as waste incinerators and metallurgical processes, and areal sources, such as landfills, wastewater treatment plants and other small but cumulative urban and rural sources where quantification is in its infancy. This report, along with supporting documentation, provides guidance and encouragement to governments and others to extend the application of the described science to the identification and, as necessary, control of sources of those persistent toxics substances that threaten the health of the Great Lakes and its inhabitants.

During the 1999-2001 priority work cycle, the International Air Quality Advisory Board (IAQAB) and the Great Lakes Science Advisory Board (SAB) held two workshops, in cooperation with the Delta Institute, focussing on the capability of atmospheric models to support the development of policies, including source control strategies, by confirming deposition trends and identifying significant sources of persistent contaminants.

The breadth of science discussed at the workshops extended well beyond what is discussed in this chapter. A CD-ROM titled *Atmospheric Deposition: Science and Policy*, containing background papers, presentation materials and a record of the related discussions, is available on request from the Great Lakes Regional Office of the IJC.

The workshop held in Milwaukee, Wisconsin in November 2000, drew upon the findings of the first workshop in Ann Arbor, Michigan and focussed particularly on Lake Michigan. Background papers from leading scientists were reviewed by government policy personnel, academics, consultants and industrial and public interest groups. The Delta Institute also presented a draft strategy, which has since completed, on steps to reduce toxic air pollution to Lake Michigan. The strategy is available on the Delta Institutes web site. www.delta-institute.org

Recommended actions from the IAQAB include: completion of the Lake Michigan Mass Balance Study for pathways other than atmospheric deposition; extension of that Mass Balance to other contaminants; improvement of emission inventories, particularly for point and areal dioxin sources within 100 km of the Lake Michigan basin and for dominant areal, and largely unquantified sources of PCBs and other banned contaminants; development of a predictive, first estimate model for areal urban emissions of banned contaminants; use of models to estimate emissions of residual banned pesticides from agricultural practices; and the continuation and extension of enhanced ambient measurement schemes to better estimate areal and regional loading and support model verification.

Annex 15: Airborne Toxic Substances, committed the governments of the United States and Canada, the parties to the Agreement, to the reduction of atmospheric deposition of toxic substances, particularly persistent toxic substances, to the Great Lakes basin ecosystem through research, surveillance and monitoring, and ultimately, the implementation of additional pollution control measures.

The two workshops were held to further examine issues contained in the Great Lakes Water Quality Agreement. *Annex 15: Airborne Toxic Substances,* committed the governments of the United States and Canada, the parties to the Agreement, to the reduction of atmospheric deposition of toxic substances, particularly persistent toxic substances, to the Great Lakes basin ecosystem through research, surveillance and monitoring, and ultimately, the implementation of additional pollution control measures. Models to determine the significance of atmospheric loadings to the Great Lakes system, relative to other pathways, and the sources of such substances from within and outside the Great Lakes system, also were to be developed.

The Integrated Atmospheric Deposition Network (IADN) was established in the Great Lakes basin as a direct response

to Annex 15 and built upon the expertise available under the IJC for its design. The network was designed to: 1. determine atmospheric loadings of toxic substances by quantifying their total and net atmospheric input to the Great Lakes system; 2. define the temporal and spatial trends in the atmospheric deposition in the basin; and 3. support development of Remedial Action Plans and Lakewide Management Plans pursuant to Annex 2 of the Agreement.

Additionally, the Parties, in cooperation with state and provincial governments, committed to develop and implement measures to control emission of toxic substances and eliminate the sources of persistent toxic substances in cases where the atmosphere is a significant contributor to the Great Lakes system. The governments were to review their progress in implementing this annex and report to the IJC biennially, commencing with a report no later than December 31, 1988.

Appendix I contains a history of significant activities that have taken place since 1987 under Annex 15: Airborne Toxic Substances of the Great Lakes Water Quality Agreement. This history provides helpful background information leading up to the current work of the IAQAB.

4.2 ANN ARBOR, MICHIGAN WORKSHOP, JULY 2000

In July 2000, the Delta Institute, IAQAB and SAB collaborated on a workshop entitled *The Use of Atmospheric Modeling In Policy Development* in Ann Arbor, Michigan. Discussion focussed on the quantity and quality of model results necessary for use in initiating or modifying policy affecting the transport and deposition of persistent toxic substances. There was agreement that models provide a useful and necessary contribution to the scientific understanding of atmospheric deposition of toxic substances and, as reflected in the evolution of the U.S. ozone regulations, could play a prominent role in policy formulation. However, from the perspective of the decision makers, the issue of model capability has not been adequately addressed.

The Ann Arbor workshop reiterated several needs identified in earlier Delta Institute and IJC events including: chemical speciation of emissions and other improvements in emission inventories; further fundamental research into the physical and chemical properties of persistent toxic substances; use of appropriate meteorological data; and additional ambient measurements to verify model outputs. In some cases, finer spatial scale resolution in meteorological databases to account for urban and agricultural plumes and the subsequent volatilization and transport of previously deposited contaminants from the lakes to the atmosphere, the grasshopper effect, would be needed. More research on large particle transport and scavenging and deposition processes also were seen as necessary.

Policy makers noted that they operate in a complex environment where other models, such as those associated with risk analysis and socioeconomic factors, enter into the decision-making process. Localized air pollution modelling associated with the permitting of single sources was familiar, but further exposure to regional- and continental-scale modelling was necessary for such tools to gain acceptance in toxics management. It was felt that an understanding of what is behind an estimated deposition number and the strengths and weaknesses associated with that estimate would be required before model outputs would be prominent in the formulation of persistent toxic reduction strategies. Some further linkage among these larger-scale deposition models and risk analysis and socio-economic models would also be desirable.

Workshop participants concluded that clarifying and ranking questions with the most urgent policy implications, as well as establishing the degree of scientific certainty required of models used to support policy development, were necessary exercises among a broad base of stakeholders. Database developers, model developers, model users, policy makers and the affected communities should be brought together to determine together how to better link data collection, modelling and policy activities.

4.3 MILWAUKEE, WISCONSIN WORKSHOP, NOVEMBER 2000

4.3.1 Goals and Structure

The second workshop, *Using Models to Develop Air Toxics Reduction Strategies: Lake Michigan as a Test Case*, sponsored by the Lake Michigan Forum, Delta Institute, IAQAB and the SAB, was held November 8 - 9, 2000 in Milwaukee, Wisconsin.

The objectives of the workshop were to:

- examine trends in air toxics deposition using several different models;
- identify strategic reduction opportunities based on these scientific findings; and
- develop a policy framework for reducing air toxics deposition to the Lake Michigan region as a test case.

The rich database available from the Lake Michigan Mass Balance Study was used by workshop participants to illustrate the use of models in support of policy strategies, explain the uncertainties associated with existing models, and identify policy strategies applicable to the Lake Michigan basin and relevant to other lake basins.

At the workshop, presentations from leading researchers and modelers were followed by discussion of the policy implications of their work. Participants included representatives of municipal, state and provincial governments, the U.S. and Canadian governments, universities, consultants, industry and environmental groups. Included were researchers, modelers, regulatory personnel, policy makers and advocates for industry and the public interest. Representatives from the Lake Michigan Forum, IAQAB, Great Lakes Commission and U.S. EPA staff working on lakewide management plans, the Great Waters program, the Lake Michigan Mass Balance Study and Total Maximum Daily Loads were among those participating.

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To provide background in the current science, the workshop sponsors commissioned papers on various aspects of atmospheric deposition from prominent scientists in the field. Included were unpublished results of modelling studies applicable to the Great Lakes basin, particularly Lake Michigan, as well as relevant information from studies elsewhere. In presenting these papers, researchers were asked to emphasize the policy and source control implications of their model findings and to address uncertainties and resource requirements associated with the application of their models. A list of the presentations is provided in Table 1.

A second element of the workshop focussed on the development of a preliminary strategy to address atmospheric deposition of persistent toxic substances to Lake Michigan for use in the Lakewide Management Plan. Prior to the workshop, a draft strategy prepared by the Delta Institute was distributed to participants. The draft strategy evaluated the potential of existing state and federal control approaches to respond to information from atmospheric models, proposed a strategy for using policy tools in the Lake Michigan basin and identified unresolved policy questions to which models could respond.

Recommended actions from the Delta Institute strategy included:

- creation of an adequate monitoring network and comprehensive emission inventories; enhancement of regional modelling efforts;
- examination of the implications of urban air toxics initiatives;
- application of environmental management systems;
- extension of pollution prevention techniques to agricultural practices;
- consideration of a total maximum daily load (TMDL) calculation for Lake Michigan;
- targeted emission reductions from federal facilities; and,
- integration of reduction targets into energy policies.

Table 1 **Invited Presentations: IAQAB/Delta Institute, Milwaukee Workshop**
Using Models to Develop Air Toxics Reduction Strategies: Lake Michigan as a Test Case

The Transport and Deposition of Dioxin to Lake Michigan: A Case Study	Mark Cohen	NOAA Air Resources Research Laboratory Silver Spring, Maryland
Lessons from Modeling Contaminants in Other Large Water Bodies: Identifying Origin and Time Responses of HCHs in the Baltic Sea	Frank Wania	Wania Environmental Chemists Corp and Division of Physical Sciences University of Toronto at Scarborough Toronto, Ontario
A Modeling Assessment of the Impact of Pesticide Application Methods and Tilling Practices on Emissions to the Atmosphere	M. Trevor Scholtz	Canadian Global Emissions Interpretation Centre Mississauga, Ontario
Exchange of Atmospheric Chemicals with Urban Surface Waters: Controls on Long-Term Response Times	Joel Baker	Chesapeake Biological Laboratory University of Maryland Solomons, Maryland
The Use of Receptor Models to Locate Atmospheric Pollutant Sources: PCBs in Chicago	Ying-Kuang Hsu	Department of Civil and Environmental Engineering Clarkson University, Potsdam, New York
Polychlorinated Biphenyl Emissions to Urban Atmospheres: Enhanced Concentrations, Atmospheric Dynamics and Controlling Processes	Steven Eisenrich	Department of Environmental Sciences Rutgers University, New Brunswick, New Jersey
The Impact of Chicago on Lake Michigan: Results of the Lake Michigan Mass Balance Study	Keri Hornbuckle	Department of Civil and Environmental Engineering, University of Iowa, Iowa City, Iowa

It was recommended that these and other approaches be considered under the Binational Toxics Strategy and during the reauthorization of the U.S. Clean Air Act.

During the workshop, facilitated small group discussions focussed on the following questions.

- What are the most important ideas (policy and science) learned or heard to that point in the workshop?
- What are initial reactions to strategy elements laid out in the draft strategy?
- Are there any key ideas or elements that are missing?
- What would be the best way to track progress on specific aspects of the strategy or on the strategy as a whole?

Based on feedback provided during the workshop, the Delta Institute refined its strategy. It focuses on generic recommendations for actions necessary to provide information to support policies and programs for the reduction of atmospheric transport and deposition of persistent toxic substances into the Great Lakes from local, regional, national and international sources. The strategy is available on the Delta Institute web site. http://www.delta-institute.org.

4.3.2 Description of Modellers and their Applied Models

Dr. Mark Cohen

Dr. Mark Cohen outlined his use of a modified version of the NOAA HYSPLIT-4 (Hybrid Single Particle Lagrangian Integrated Trajectory) model to simulate atmospheric fate and transport of dioxin from sources in the U.S. and Canada to Lake Michigan and the other Great Lakes. In this model, puffs of pollutant are emitted from user-specified locations and advected, dispersed and subjected to destruction and deposition phenomena. Using meteorological output from NOAA's Nested Grid Model, the dioxin model simulates vapor and particle partitioning, wet and dry deposition,

reaction with the hydroxyl radical and photolysis during the transport and deposition process.

With the support of the IAQAB and U.S. and Canadian environmental agencies, Dr. Cohen and his former coworkers at the Center for the Biology of Natural Systems, SUNY Queens College, developed a dioxin emission inventory based on U.S. EPA and Environment Canada inventories. This included additional source specific and contaminant speciation information and estimates on several other source categories including residential waste (backyard) burning. The current inventory contains over 5,700 point sources. Area sources, such as mobile sources and backyard burning, were estimated at the county level in the U.S. and within 50 or 100 km grids in Canada.

Dr. Frank Wania

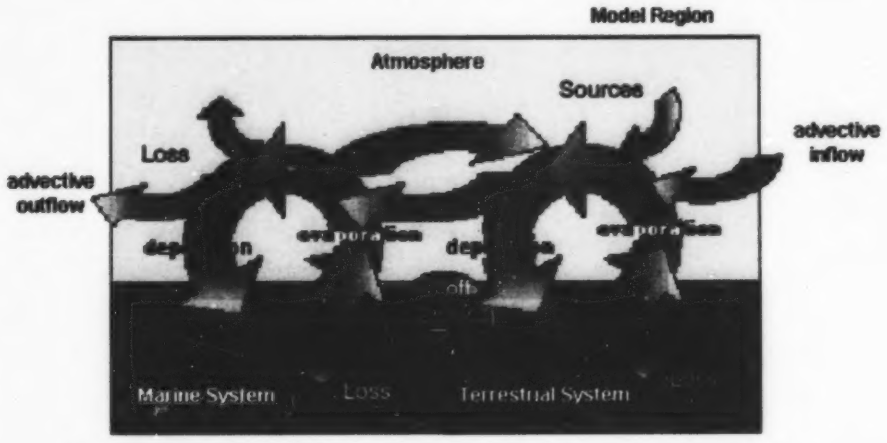
The POPCYCLING-Baltic model used by Dr. Frank Wania describes an entire regional environment, including the atmosphere, marine system and terrestrial system, and estimates the fractions of persistent toxic substances in various 'well mixed' environmental compartments and the fluxes or exchanges between them. Contaminants are associated with recent and past releases in the drainage basin and air masses advected into the region. The model integrates information on partitioning, transport and transformation to estimate distribution of the contaminant within this simplified system.

Key processes include exchanges between the atmosphere and aquatic and terrestrial surfaces, and runoff from soil via fresh water to the sea. The Baltic Sea environment is described in the model using four atmospheric, 16 marine and 15 marine sediment components, as well as 10 drainage basins composed of five compartments each (forest canopy, forest soil, agricultural soil, fresh water, fresh water sediment), as shown in Figure a. As this model is meant to calculate long-term trends (on the scale of years to decades), it employs average monthly values for atmospheric transport rates, temperature, wind speed and hydroxyl radical concentration. Other environmental parameters, in particular those relating to water and organic carbon cycling in the Baltic Sea, are assumed fixed in time. The 85 differential mass balance equations are solved in a step-wise fashion with a finite difference approximation using a time step of six hours.

Dr. Trevor Scholtz

Dr. Trevor Scholtz used the Canadian Global Emission Interpretation Centre's Pesticide Emissions Model (PEM) to derive theoretical emissions, over a three-year period, of twenty pesticides applied to soil by various means including incorporation, surface spraying and in-furrow application at time of planting. PEM, which solves for moisture and pesticide concentration and the advection and diffusion of heat in agricultural soils, is driven by hourly meteorological data.

Figure b. shows the main modules and the input data requirements of the PEM model. A relatively large number of soil levels, 45 variably spaced levels over a one-metre soil depth, is utilized to define the pesticide concentration profile for computation of the volatilization rate. At the surface,



The POPCYCLING-Baltic model aims to quantify the pathways of POPs from the terrestrial environment to the marine environment via atmosphere and rivers

Figure a. The POPCYCLING-Baltic Model

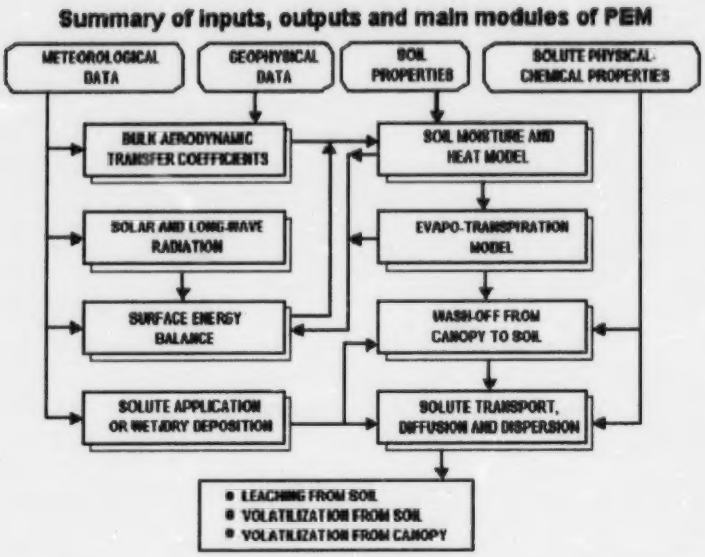


Figure b. **Summary of inputs, outputs and main modules of PEM**

PEM is coupled to the adjacent atmospheric layer through a surface energy balance. Sensible and latent heat fluxes are modeled using similarity theory for the atmospheric surface layer, while radiative heat fluxes are estimated using a simple model employing incoming solar radiation at the ground surface. PEM is also coupled to a modified 'big leaf' canopy submodel that includes interception of post-emergent spray by the canopy as well as subsequent volatilization and/or wash off during precipitation events. The time dependent, one-dimensional governing equations for heat, moisture and pesticide concentration are solved using a finite element technique with a time step of 1,200 seconds.

Ying-Kuang Hsu and Dr. Tom Holsen

Ying-Kuang Hsu and Dr. Tom Holsen used the Potential Source Contribution Function (PSCF) to identify PCB sources at the southern end of Lake Michigan. Receptor models, such as the PSCF, focus on the behavior of the contaminant in the ambient environment at the point of impact or detection, as opposed to dispersion models that focus on transport, dilution and transformations between the source and receptor. The PSCF incorporates wind trajectories to attempt resolution of locations for unknown pollutant sources.

PSCF model statistics count each trajectory segment endpoint terminating within a particular grid cell to determine the probability that an event at the receptor site is related to that cell. The NOAA HYSPLIT-4 model was used to calculate backward trajectories. The PSCF value can be interpreted as the conditional probability that concentrations larger than a given criterion value are related to the passage of air parcels through that cell during transport to the receptor site, with high cell PSCF values indicating areas of high potential pollutant contributions. This is illustrated in Figure c., where the source is located in cell C11 and the receptor is in C45. Solid curves represent high concentration wind trajectories and dotted lines represent low concentration wind trajectories.

Dr. Keri Hornbuckle

As part of the U.S. EPA's Lake Michigan Mass Balance Study, Dr. Keri Hornbuckle constructed a predictive model for gas-phase PCB congeners and trans-nonachlor over Lake

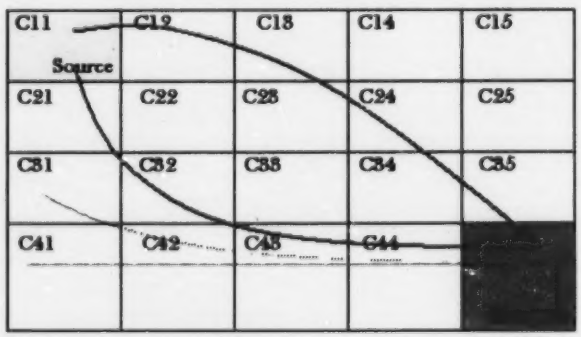


Figure c. **Potential Source Contribution Function (PSCF)**

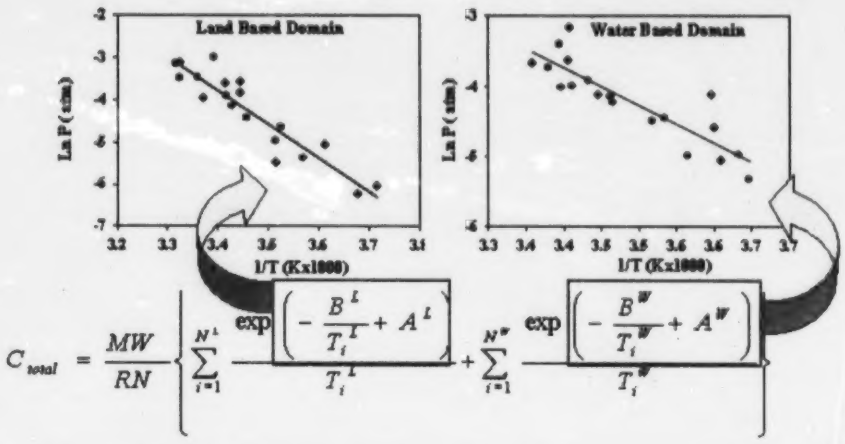

Land Based Domain
Water Based Domain
Ln P (sim)
1/T (Kx1000)
$C_{total} = \frac{MW}{RN}\left\{\sum_{i=1}^{N^L} \frac{\exp\left(-\frac{B^L}{T_i^L} + A^L\right)}{T_i^L} + \sum_{i=1}^{N^W} \frac{\exp\left(-\frac{B^W}{T_i^W} + A^W\right)}{T_i^W}\right\}$

Figure d. Stochastic Fractionation

Michigan using air temperature, wind direction and atmospheric PCB concentration data collected around and over the lake. A twofold approach is used to estimate the concentration of gas-phase chemicals over the lake, predicting the daily variation in gas-phase concentrations at each site, and then interpolating the discrete site predictions over the entire surface area of the lake.

As shown in Figure d., a best fit equation of the temporal variation in gas-phase concentrations is derived for each site as a function of the number of hours that the land domain was sampled; the number of hours that the water domain was sampled; air temperature for the air flow over the land; air temperature for air flow over the water; and four fitting coefficients. After predicting the daily concentrations at each of the eight shoreline sites and 12 over-water sites, these concentrations were interpolated to predict concentrations at all of the approximately 2,300 cells over the lake, using an inverse distance weighting approach.

4.3.3 Estimated Extent of Deposition of Selected Contaminants to Lake Michigan

Dioxin

Dr. Mark Cohen of the Air Resources Laboratory of the National Oceanic and Atmospheric Agency described his application of the NOAA HYSPLIT-4 (Hybrid Single Particle Lagrangian Integrated Trajectory) model to evaluate the atmospheric fate and transport of dioxin from U.S. and Canadian sources to the Great Lakes. Emission inventories used as input to the model are summarized in Figures e. and f. This source-receptor model estimated the total dioxin flux to Lake Michigan for the year 1996 to be on the order of 5 - 50 grams TEQ per year, with a central estimate of approximately 17 grams TEQ per year. Incineration, particularly of municipal, medical and hazardous waste, along with metallurgical processing, continue to be the dominant known source sectors contributing dioxin to the Great Lakes via the atmospheric pathway.

Sources from as far away as 2,500 km contributed dioxin to Lake Michigan; however, the model indicated that approximately 40 percent of all dioxin deposition to the lake originates from within 100 km. Figure g. illustrates the magnitude and geographic distribution of North American sources of dioxin deposition to Lake Michigan, based on the Cohen model.

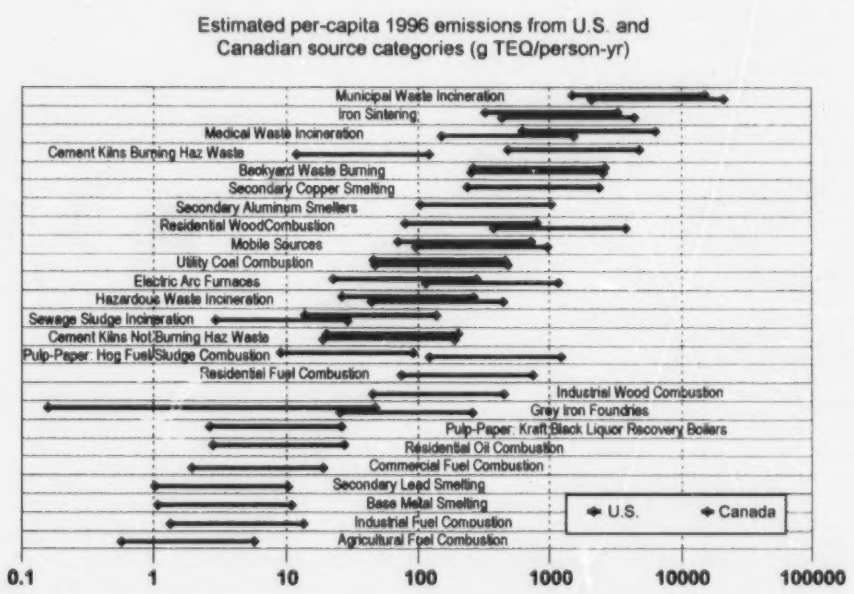


Figure e. Estimated 1996 Per-Capita PCDD/F Emissions (g TEQ/person-yr)

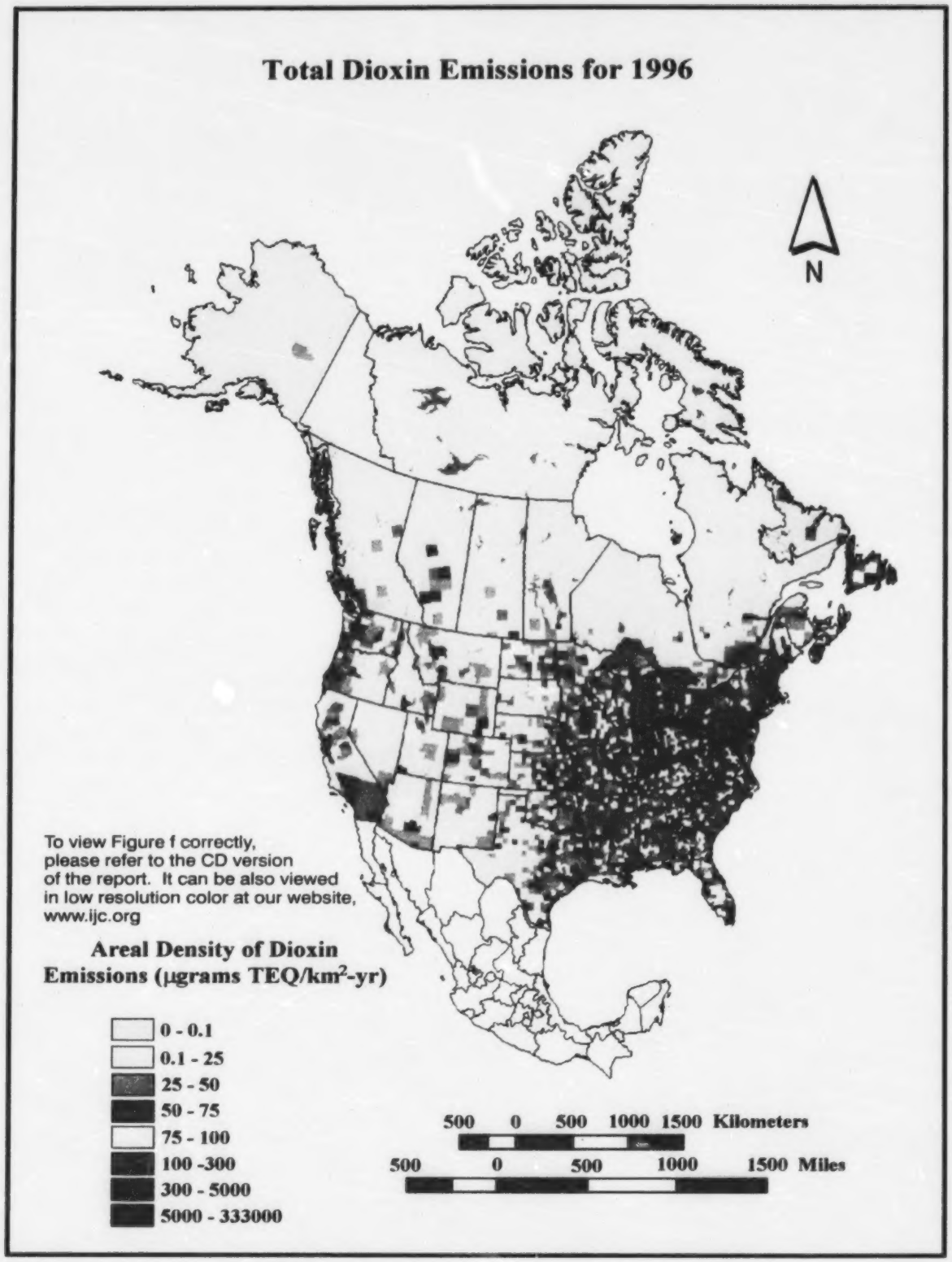

Total Dioxin Emissions for 1996
N
To view Figure f correctly, please refer to the CD version of the report. It can be also viewed in low resolution color at our website, www.ijc.org
Areal Density of Dioxin Emissions (µgrams TEQ/km²-yr)
0 - 0.1
0.1 - 25
25 - 50
50 - 75
75 - 100
100 -300
300 - 5000
5000 - 333000
500 0 500 1000 1500 Kilometers
500 0 500 1000 1500 Miles

Figure f. Total Dioxin Emissions for 1996

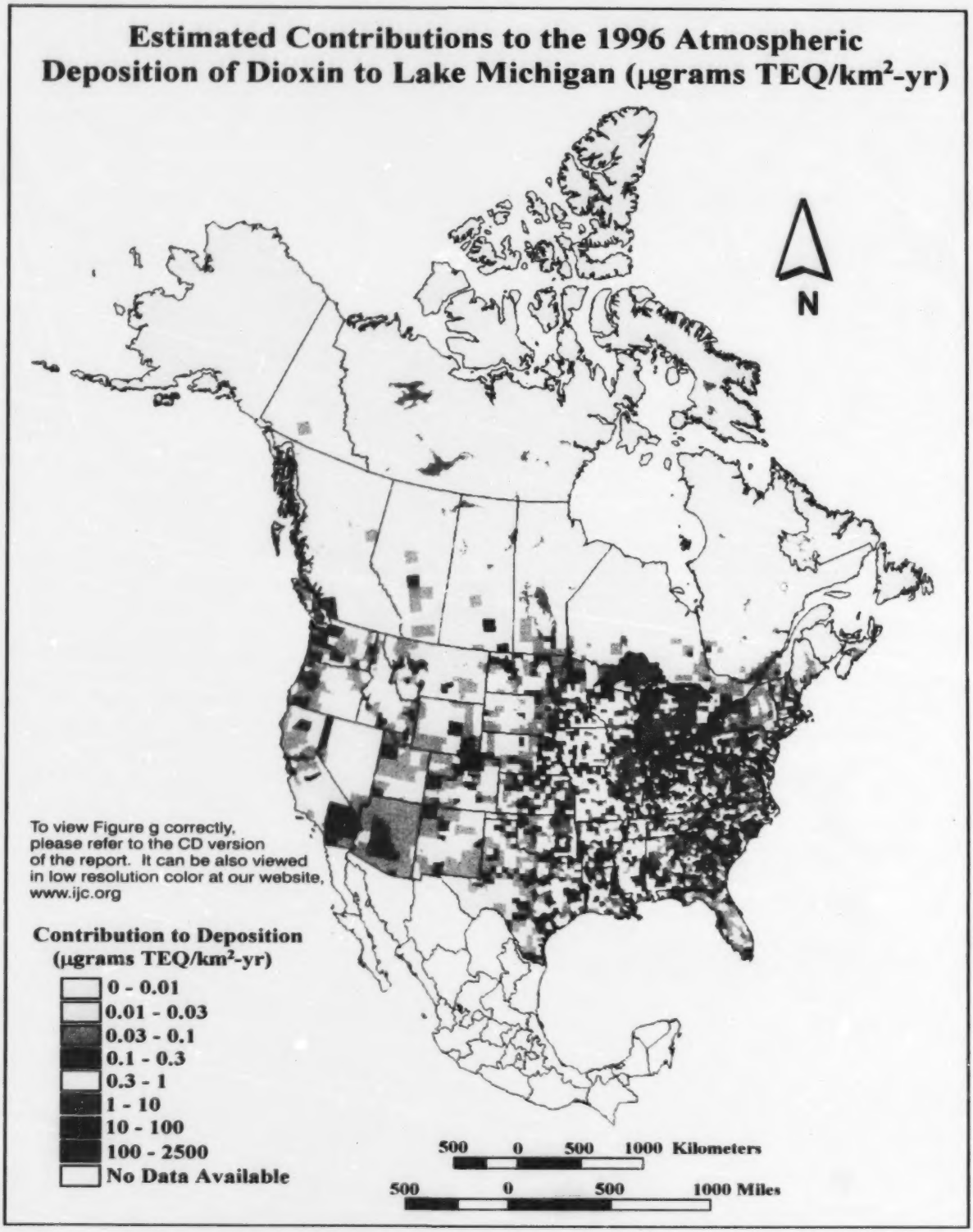

Estimated Contributions to the 1996 Atmospheric Deposition of Dioxin to Lake Michigan (µgrams TEQ/km²-yr)
N
To view Figure g correctly, please refer to the CD version of the report. It can be also viewed in low resolution color at our website, www.ijc.org
Contribution to Deposition (µgrams TEQ/km²-yr)
0 - 0.01
0.01 - 0.03
0.03 - 0.1
0.1 - 0.3
0.3 - 1
1 - 10
10 - 100
100 - 2500
No Data Available
500 0 500 1000 Kilometers
500 0 500 1000 Miles

Figure g. Estimated Contributions to the 1996 Atmospheric Deposition of Dioxin to Lake Michigan (µgrams TEQ/km²-yr)

Figure h. indicates the distribution of sources of total dioxin emissions in North America within various distances of each of the Great Lakes and the distribution of sources of dioxin deposition to each of the lakes with distance. The peak in total emission sources for Lake Michigan occurs at a distance between 700 - 1,000 km, while the peak in total deposition to Lake Michigan occurs from sources within 0 - 100 km. This suggests that the more proximate sources (those within 100 km of the basin), while their aggregate emissions are less, are linked to a very significant fraction, 40 percent, of the deposition in that lake.

Figure h. shows that this trend of greater deposition impact by proximate sources is not as significant for the other Great Lakes, as the majority of dioxin deposition arises from more distant sources.

In Figure i., a summary of sensitivity analyses is presented for deposition to Lake Superior, in order to illustrate the relative magnitude and range of uncertainties in the overall simulation. The influence of six different aspects of the simulation on the model-predicted deposition is shown, including the number of standard source locations used to determine theoretical transfer (84 vs. 28), the interpolation methodology, the photolysis rate, the characterization of wet and dry deposition and the emissions themselves.

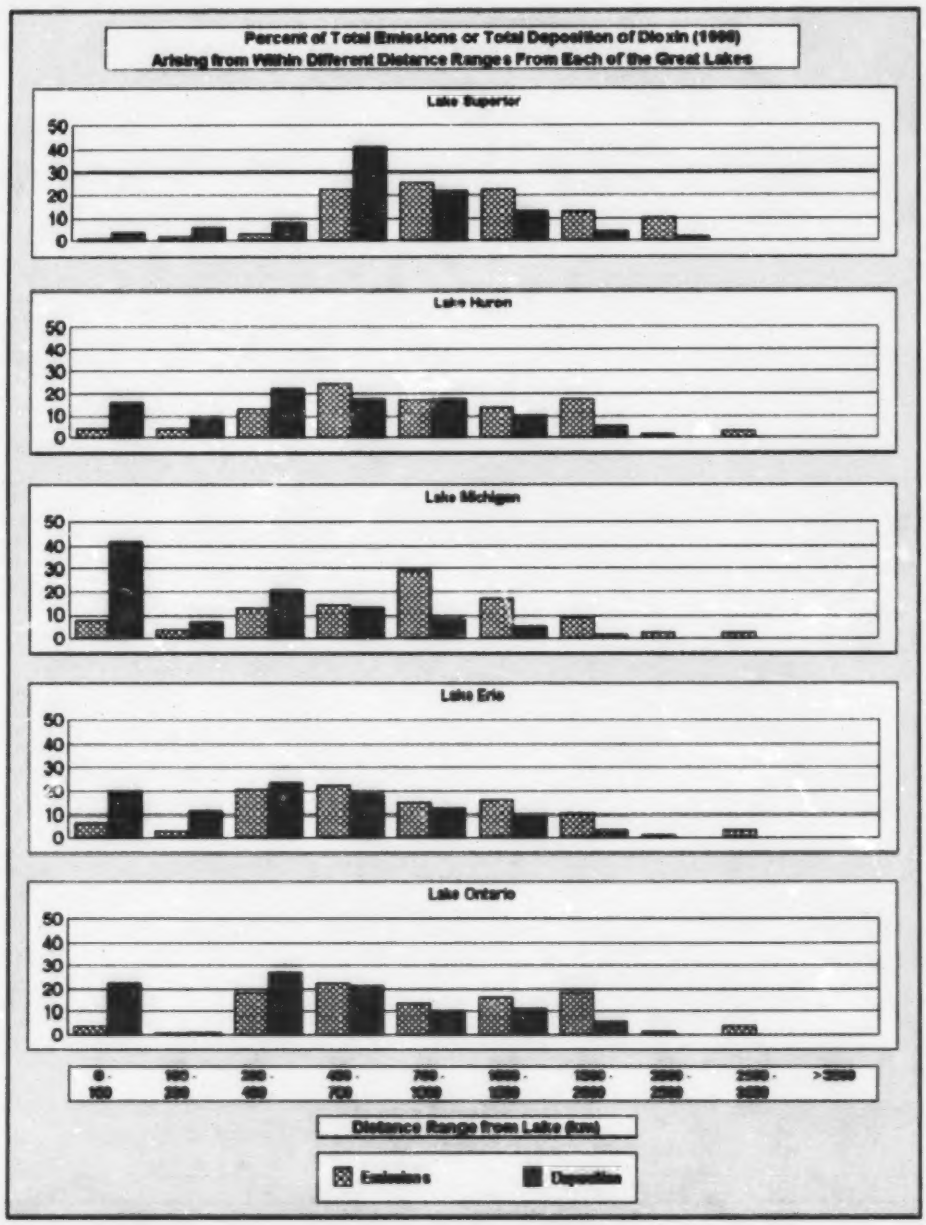


Figure h. Percent of Total Emissions or Total Deposition of Dioxin (1996) from Within Different Distance Ranges from Each of the Great Lakes

In some cases, the distribution was explicitly evaluated in the sensitivity analysis in only one direction or in a fairly limited manner. This was true for wet deposition, where the sensitivity analysis consisted of increasing the in-cloud particle washout ratio by a factor of four, photolysis, where the photolysis rate was decreased essentially to zero, and the number of standard source locations, where only two variations were evaluated (28 vs. 84 locations).

In these situations, where a more complete analysis of the influence of the methodological variation would have included variations in the other direction (e.g. a decrease in the in-cloud particle washout ratio) to

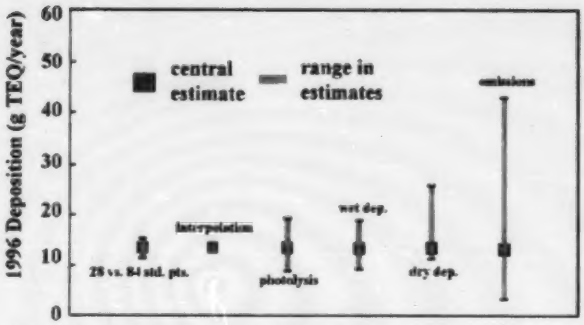


Figure i. Approximate range of uncertainties in estimating total 1996 PCDD/F deposition to Lake Superior

determine the magnitude of the band of possible annual deposition, one of the endpoints of the uncertainty range was inferred by assuming that the influence of variations was approximately the same on either side of the central estimate. To estimate the impact of uncertainty in the emissions, the low end and high end of the estimated emissions range were used for each source.

It can be seen from Figure i. that uncertainties arising from the interpolation procedures appear relatively insignificant, those for the fate methodologies are moderate, and the uncertainty arising from the emission estimates appears relatively significant. While not shown here, results for the other Great Lakes are comparable to these for Lake Superior.

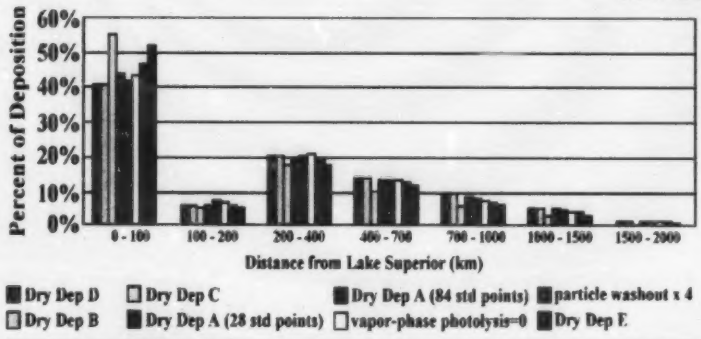


Figure j. Effect of fate simulation variations on the geographical pattern of deposition contributions to Lake Michigan

While uncertainties in the fate simulation methodology result in significant uncertainties in the magnitude of the model-predicted deposition to the Great Lakes, the estimates of the relative importance of different sources or source regions are not strongly affected. Examples of this are shown in Figure j. and Figure k. for Lake Michigan. In these figures, the effects of the most significant fate variations are examined, including the dry deposition algorithms used, wet deposition, and photolysis. Each set of estimates in these figures represents a complete model analysis with a given set of parameters and/or algorithms. Note that the default estimate is that for dry deposition algorithm "A."

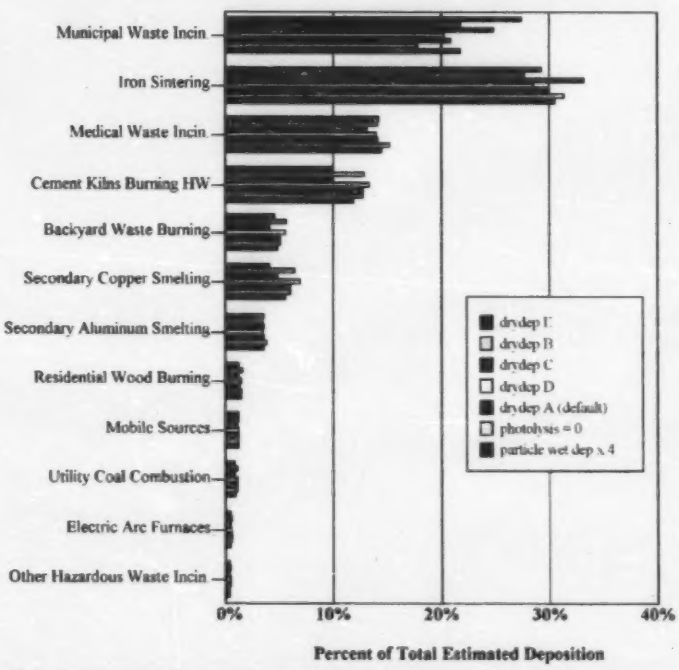


Figure k. Effect of fate simulation variations on the relative contribution of different source categories to 1996 atmospheric deposition of dioxin to L. Michigan (for top 12 categories)

Uncertainties in emissions have a pronounced affect on the overall predicted deposition and a direct effect on the estimates of the relative importance of different sources and source regions. For example, the relative significance of backyard burning and its contribution to emission estimate uncertainty remains a question. Cohen used a dioxin emission factor of approximately 250 grams TEQ per year for backyard burning, which would be approximately 10 percent of the total U.S. dioxin inventory. Burn barrel test data vary significantly, yielding orders of magnitude differences in estimated emission factors. Actual annual emissions may be as high as 1,000 or 2,000 grams or could also be significantly below the modeled estimate. Determining the significance of this source should be addressed promptly through appropriate research. Uncertainties in other source categories are also very significant. It was stressed that uncertainties in emissions are the controlling source of uncertainty in this type of analysis and further progress would require the directing of additional resources toward improving and updating emission inventories.

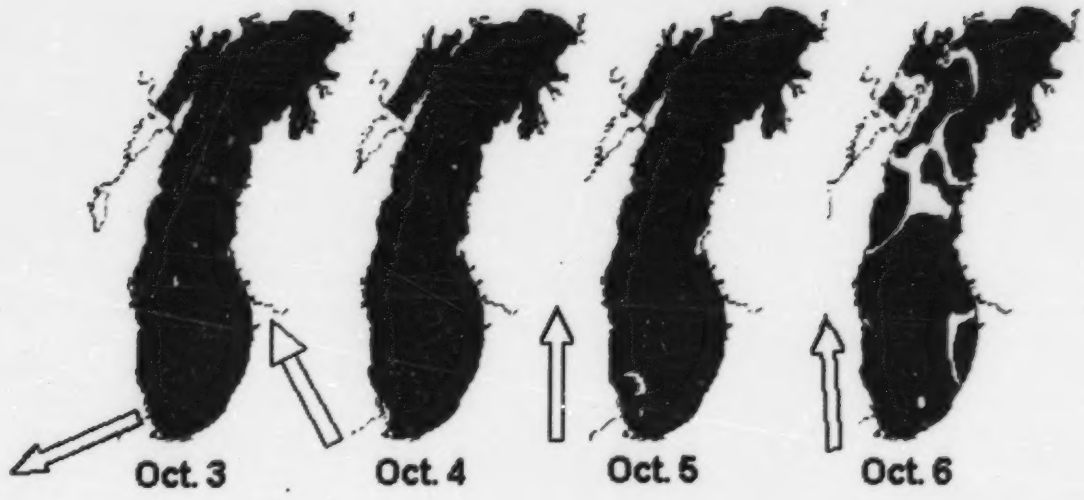


Figure 1. Net Gas-Exchange of ΣPCBs

Polychlorinated Biphenyls (PCBs)

Deposition of gas-phase organic chemicals, including PCBs, is a major contributor to the loading of persistent toxic substances to Lake Michigan and, in the case of PCBs, up to 90 percent of the atmospheric concentration is associated with the free vapor phase. Not only is gas exchange the dominant process, it also occurs quite rapidly. Dr. Joel Baker emphasized the close linkage between the concentrations of PCBs and other volatile contaminants in the atmosphere and in the waters of the Great Lakes. Atmospheric gas exchange flux estimates indicate that somewhere near 20 or 40 nanograms of PCBs per square meter of lake surface per day (ng/m^2/day) are being continually exchanged between the atmosphere and Lake Michigan. Up to 10 percent of the PCBs in the atmosphere exchange with the surface waters of Lake Michigan every day.

Baker estimates that 90 percent of the uncertainty in the gas exchange flux calculation is associated with the mass transfer coefficient and noted that focussed research to better understand air-water exchange physics would be critical to improvement of flux estimates. Gas exchange cannot be easily measured and must be estimated. As air and water PCB inventories approach steady state, it is increasingly difficult to calculate the air-water exchange rate.

Dr. Keri Hornbuckle discussed the application of a predictive model for persistent organic compounds, developed as part of the Lake Michigan Mass Balance Study, to the estimation of PCBs over Lake Michigan. Concentrations of 30 gas-phase PCB congeners and the sum of approximately 100 individually measured congeners or coeluting congener groups were estimated for every day of the 18-month field season and in the air over each of approximately 2,300 cells of lake surface area.

Measurements over such a fine scale grid allowed the estimation of variability of atmospheric deposition over space and time resulting in a model useful in the prediction of the spatial impact of the Chicago source area. A twofold approach is applied to the estimation of the concentration of gas-phase PCBs over the lake, first predicting the daily variation in gas-phase concentrations at each site based on wind direction and temperature, then interpolating the discrete site predictions over the entire surface area of Lake Michigan.

Hornbuckle determined net gas exchange of PCBs as a function of gas-phase concentrations, dissolved water concentrations, the physical and chemical properties of the compounds, wind speed and surface water temperatures. The resulting air/water exchange fluxes for PCBs exhibit intense variability over space and time, as well as in the direction of flux between net deposition and net volatilization.

Both air temperature and wind direction are strong factors in the variability in gas-phase PCB concentrations over Lake Michigan. Under low temperature and northern wind regimes, PCBs exhibit volatilization (transfer from the lake to the atmosphere) fluxes over most of the lake, primarily due to low air concentrations during cooler weather and negligible transport of air from the Chicago area over the lake. Figure 1. illustrates four distinct daily scenarios.

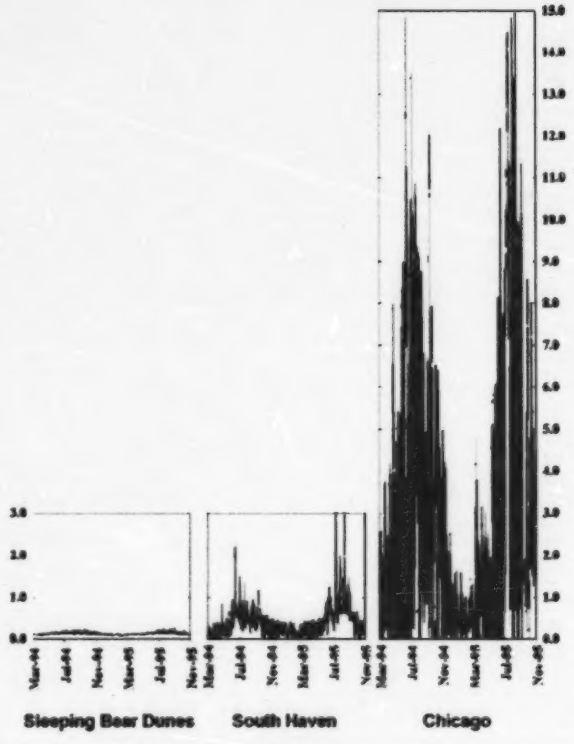


Figure m. **Averaged PCB Concentrations over Time (ng/m³), Chicago and Two Representative Background Sites**

For October 3, 1994, a day with primarily northeasterly winds and cool temperatures, volatilization is dominant. On the following day, the winds were primarily southeasterly and the Hornbuckle model predicted a small region of PCB deposition (transfer from atmosphere to lake) flux just north of the Chicago area. On October 5 and 6, the winds were predominantly southerly and the Chicago PCB plume causes a larger region of deposition to the lake. On October 6, the deposition zone covers almost the entire lake as a result of increased ambient temperatures and prevailing winds from the Chicago area. Although most of the southern basin of the lake experiences net gas deposition of PCBs, there are large regions along the southern coasts that still exhibit volatilization fluxes, primarily a result of gas-phase concentration variability across the lake. Water temperatures and the prevailing localized wind directions at each of the sampling sites also contribute to this complex pattern of air/water exchange. The model predicts large variations in gas-phase concentrations of PCBs at all of the Lake Michigan Mass Balance Study measurement sites, due principally to substantial changes in wind direction and temperature. Figure m. contrasts the extreme variability in predicted daily concentrations of gas-phase PCBs at Chicago with more stable values from open lake and the Sleeping Bear Dunes regional IADN monitoring site on the eastern shore of the lake. These significant changes in concentrations in the air mass coming from or through Chicago result in very large, often diurnal, variations in the area of Lake Michigan affected by the Chicago plume.

The Sleeping Bear Dunes site clearly registers lower ambient concentrations of PCBs than measurements taken elsewhere in the Lake Michigan basin, including measurements taken over water. The signal from this site is not directly correlated with temperature; suggesting other more complex factors must be considered. However, regardless of cause, this evident underestimation may preclude use of these data alone as representative of regional PCB concentrations without further corroboration with measurements from both other land based and over-water sites.

Also, due to the large daily variations in air concentrations and depositional fluxes, future studies should be integrated over larger time periods and larger areas, and should consider the impact of Chicago on deposition load, rather than attempting to define an area of impact, which can be highly variable.

Hornbuckle *et al* calculated the contribution of Chicago to the total gas-phase loading of PCBs to Lake Michigan as total gross gas deposition and net gas exchange. This approach removes the effect of water concentrations and associated transfers, which exhibit some seasonal and spatial variability, and allows for better integration of the contribution of each individual site.

For the whole lake, *gross* annual deposition of PCBs, the sum of the modelling results for all 98 congener groups, was approximately 3,200 kg. The results indicated the percent contribution of the Chicago site to the whole lake monthly gas-phase loads ranged from less than five percent to 20 percent, depending on the congener and the month. On an annual basis, Chicago is the largest single source of all 20 sites considered, contributing 10 percent of the total annual deposition load of gas-phase PCBs.

In his presentation, Dr. Steve Eisenreich showed that, as indicated for Chicago in the Lake Michigan research, over-water PCB concentrations are elevated downwind of the Baltimore and New York urban areas. On average, over-water concentrations were enhanced by a factor of four over regional background values. This pattern also was observed in the Chesapeake Bay near Baltimore and the New York harbor estuary.

Table 2 provides data from the Atmospheric Exchange over Lakes and Oceans Study (AEOLOS), Lake Michigan Mass Balance Study and New Jersey Atmospheric Deposition Network (NJADN) data sets, illustrating enhanced urban

Table 2. Enhanced Urban Concentrations of Atmospheric PCBs

	ΣPCBs (pg/m³)		
Site	Urban Range	Over-Water or Background Range	References
Chicago- AEOLOS 1994 - 1995	270 - 14000	130 - 1200 70 - 800	Simcik *et al*, 1997 Zhang *et al*, 1999
Chicago - LMMB 1994 - 1995	500 - 6800	100 - 500 (Sleeping Bear Dunes)	Miller *et al*, 2001
Chicago - LMMB 1994 - 1995	100 - 16000 (modeled - 24 hr. day)	43 - 440 (modeled - 24 hr. day Beaver Island)	Green *et al*, 2000
Chicago - IADN 1998 1999	 460 - 6800 335 - 7000		Hites and Basu, Unpubl. data
Baltimore - AEOLOS June 1996	380 - 3360	210 - 740	Offenberg and Baker, 1999
Baltimore - AEOLOS June 1997	760 - 2280	290 - 990	Brunciak *et al*, 2000
NY-NJ Area 1997 - 2000 (NJADN)	100 - 3300 (Jersey City)	60 - 2340 (Suburban) 90 - 1600 (Coastal)	Brunciak *et al*, 2000
Camden/Philadelphia 1999 - 2000	1020 - 16000	45 - 550 (Pinelands)	Eisenreich and Reinfelder, 2001

PCB concentrations for Chicago, Baltimore, New York - New Jersey and Camden - Philadelphia.

The Eisenreich presentation also stressed the dependence of atmospheric concentrations of PCBs, at any site, on temperature, which drives the magnitude of air-surface exchange. As illustrated in Figure n., higher ambient temperatures generate higher atmospheric PCB concentrations particularly in areas where higher surface contamination would be anticipated, such as urban and industrial environments.

Concentrations of PCBs in the urban atmosphere range from 100-300 pg/m³ in winter to 5,000 to 16,000 pg/m³ on hot summer days, based on data from Chicago, Baltimore, Jersey City and Camden - Philadelphia. Eisenreich also concludes that high ambient temperatures in contaminated areas yield high atmospheric concentrations, whose inventory is then transported away from the urban area to nearby water bodies and terrestrial landscapes. As noted earlier during the

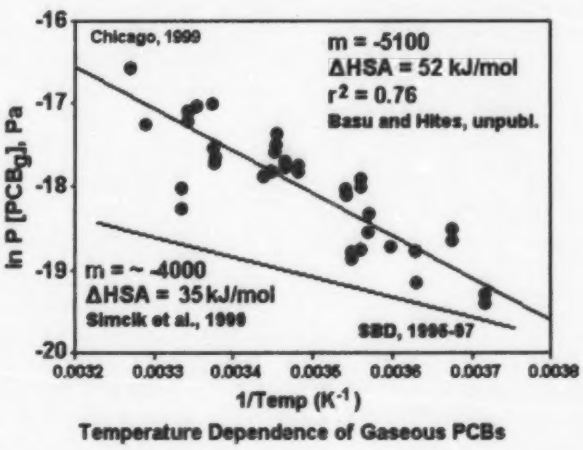


Figure n. Temperature Dependence of Gaseous PCBs

discussion of Chicago PCB data, variability in concentration is linked to ambient temperature and the size of the contributing environmental reservoir of PCBs.

Agricultural Chemicals

For pesticides, delineation of emission sources and attribution of air concentrations to those sources are extremely complex. While the primary loading of pesticides to the atmosphere occurs during application to agricultural lands, emissions from residues in soil due to historical use can also be significant. The transport and deposition in North America of banned or restricted pesticides still used in other parts of the world are also of significance. The difficulty of estimation is further compounded by the confidential status of much of the current and historic pesticide sales data.

In his presentation, Dr. Trevor Scholtz described application of a Pesticide Emission Model (PEM) to development of estimates of pesticide emission inputs for chemical transport and deposition models. His methodology allowed an assessment of the effects of pesticide application methods and tilling practices on emission of pre-emergent pesticides to the atmosphere over a three-year period following application.

Three modes of pre-emergent application were examined: incorporation into the soil, spray application to the soil surface and in-furrow application during seed planting. While the in-furrow application limits the amount of pesticide initially available at the soil surface, evaporation of moisture and subsequent tilling of the soil may both expose the pesticide for subsequent volatilization. The percentages of applied pesticide theoretically lost from the soil to the atmosphere are compared for various combinations of application method, tilling of the soil in the fall or spring, or the effect of no tilling.

The 20 selected pesticides included in the theoretical model represent a wide range of physical and chemical properties and include some analogous to those currently used in North America, as well as some that have been banned or restricted on this continent, but may be in use elsewhere. Table 3 contains estimates of the extent of loss over three years in response to variation in tilling practices for the 20 pesticides studied.

Table 3 Physical-Chemical Properties of Pesticides

Source: Background paper from T. Scholtz, found on the CD-ROM *Atmospheric Deposition: Science and Policy*, available from the IJC.

#	Pesticide	Class*	Diffusivity in Air (m^2/s)	Diffusivity in Water (m^2/s)	K_{oc} - Soil Sorption (m^3/kg)	K_H - Henry's Law Constant (dim'less)	Soil Half Life (days)
1	2,4-DB	H	4.97×10^{-6}	4.97×10^{-10}	0.5	2.36×10^{-7}	7
2	Aldrin	I	4.97×10^{-6}	4.68×10^{-10}	5.01	3.74×10^{-2}	53
3	Atrazine	H	4.97×10^{-6}	5.39×10^{-10}	0.1	1.19×10^{-7}	60
4	Chlordane	I	4.97×10^{-6}	4.51×10^{-10}	20	3.70×10^{-3}	1205
5	DDT	I	4.47×10^{-6}	4.54×10^{-10}	411	9.69×10^{-4}	1095
6	Dieldrin	I	4.97×10^{-6}	4.67×10^{-10}	12	4.60×10^{-4}	2555
7	Endosulfan	I	4.57×10^{-6}	4.72×10^{-10}	12.4	1.22×10^{-3}	50
8	Endrin	I	4.97×10^{-6}	4.67×10^{-10}	10	1.35×10^{-5}	1825
9	Fenthion	I	4.97×10^{-6}	5.21×10^{-10}	1.5	9.03×10^{-6}	34
10	-HCH	I	5.41×10^{-6}	5.48×10^{-10}	2.59	3.57×10^{-4}	400
11	Heptachlor	I	4.97×10^{-6}	4.76×10^{-10}	24	4.60×10^{-2}	219
12	Hexachlorobenzene	F	5.56×10^{-6}	5.81×10^{-10}	411	2.92×10^{-3}	365
13	Lindane	I	5.18×10^{-6}	5.48×10^{-10}	1.1	5.30×10^{-5}	400
14	Methoxychlor	I	4.97×10^{-6}	4.97×10^{-10}	79.4	4.10×10^{-4}	120
15	Metolachlor	H	4.51×10^{-6}	4.97×10^{-10}	0.2	9.10×10^{-7}	90
16	Metribuzin	H	5.79×10^{-6}	4.97×10^{-10}	0.06	9.30×10^{-8}	40
17	Mirex	I	4.97×10^{-6}	4.05×10^{-10}	3260	3.45×10^{-1}	365
18	Quintozene (PCNB)	F	5.59×10^{-6}	4.97×10^{-10}	5	4.1×10^{-5}	250
19	Toxaphene	I	4.97×10^{-6}	4.35×10^{-10}	100	1.70×10^{-4}	365
20	Triallate	H	4.67×10^{-6}	4.71×10^{-10}	2.4	4.19×10^{-4}	82

* H - herbicide; I - insecticide; F - fumigant

Scholtz concluded that applying a pesticide in a furrow that is then covered results in the least loss (less than 26 percent) of applied pesticide to the atmosphere. The second best method is soil incorporation (less than 44 percent), while the highest losses of applied pesticide to the atmosphere (up to 92 percent) result from the use of a pesticide as a pre-emergent spray. Model results also suggest that spring tilling can cause releases of chemicals associated with previous applications, with subsequent transport and deposition

Atmospheric data for trans-nonachlor collected during the Lake Michigan Mass Balance Study support predictions from the PEM of Scholtz *et al.* Trans-nonachlor is a component of chlordane, a banned pesticide formerly in wide use in the U.S. Midwest. The Lake Michigan Mass Balance Study ambient monitoring data indicated a significant source of atmospheric trans-nonachlor occurring in May (Miller *et al*, 2001). Other ambient results correlated well with the modeled trans-nonachlor in the vapor phase, with the exception of this May signal. While there is no complete explanation for this finding, the PEM suggests this could be a spring till release of this banned chemical, which is residual in the tilled soil — a release not directly correlated to temperature, but rather to activity.

4.3.4 Source Identification — Need for Enhanced Emission Inventories

Most workshop presenters stressed the need to improve and enhance current emission inventories for pollutants of concern. In his presentation, Dr. Cohen identified the major impediment to further upgrading of his model as lack of current, accurate, geographically-resolved emission inventories. Dr. Wania noted that the most likely explanation for model under and over predictions is linked to variability in the emission estimates. Dr. Eisenreich indicated that, although an appreciable amount of effort went into creating the emission inventory for the Great Lakes region for PCBs, it is not adequate to account for the concentrations, fluxes, deposition and accumulation observed around Lake Michigan.

There is a major inconsistency between the PCB source inventory and the extent of deposition in Lake Michigan. Total PCB emissions in the Great Lakes Air Toxics Emissions Inventory are estimated to be approximately 3.2 kg per year, while annual *gross* deposition to Lake Michigan is estimated at 3,200 kg per year. Similar concerns were raised regarding the dioxin inventory, especially related to open burning emissions that are very much first estimates of unknown quality.

Comparable questions could be raised about the inventories of other chemicals subject to long-range transport, particularly banned substances, such as chlordane, hexachlorocyclohexane (HCH) and toxaphene. Atmospheric deposition appears to be substantially higher than would be consistent with current total emissions in available inventories, and inventories are largely not accounting for areal or fugitive emissions. Internal inventory inconsistencies also were apparent from state to state among the Great Lakes Air Toxics inventory data, especially for areal sources of pollutants such as PCBs, dioxins and furans.

The Cohen presentation emphasized that improvement of the dioxin inventory is clearly necessary, both to ensure that all sources are accounted for and to assess their impact on the Great Lakes and other water bodies more accurately. In the case of Lake Michigan, he recommended that a thorough review of established and potential sources — point and areal — within 100 km of the lake should be given priority. As noted above, his results indicated that approximately 40 percent of the dioxin deposition arose from sources within 100 km of the lake. For Great Lakes other than Lake Michigan, the proportion of the loadings arising from within 100 km of the lake is somewhat less (see Figure h). Therefore, an emphasis on nearby sources is proportionately less important for these other lakes.

The available source testing data bank and the accuracy of the emission factor approach can be increased by:

- conducting source testing at point source facilities known or suspected to be major contributors, particularly those within 100 km of the shoreline;
- testing at particular facilities that also could be representative of source sectors for which few or no tests have ever been conducted;
- performing additional stack tests at facilities with an established source testing record to provide a more robust database for developing emission factors and to better understand the variability in emissions from individual facilities; and

- ensuring regular, accurate updates of basic information from significant sources on processes, including alterations in air pollution control equipment, activity factors and other parameters affecting emissions.

Although his model included over 5,000 North American point sources of dioxin, Cohen indicated that timely updates of the emission inventory for the 100 most significant dioxin sources in the U.S. and Canada would substantially improve model accuracy while providing some guidance and assurance to control program outcomes. In addition, as noted above, further information on significant areal sources, such as backyard burning, would also be very important.

In addition, the current U.S. dioxin inventory does not contain estimated emissions from residential or commercial coal combustion, magnesium manufacturing or small commercial incinerators. Neither the U.S. nor Canadian inventory includes emissions from open-burning of PVC-coated wires (e.g. structure and vehicle fires), asphalt production, landfill fires and landfill gas combustion, coke production, leaded gasoline combustion or petroleum refining.

4.3.5 Extent of Urban Areal Emissions for PCBs – Chicago, Baltimore and the Chesapeake Bay

The hypothesis of the Atmospheric Exchange over Lakes and Oceans Study (AEOLOS) program is that elevated concentrations of air pollutants, such as PCBs in urban areas, result in enhanced deposition to nearshore areas. In 1994 and 1995, the study established a series of sampling locations in Southern Lake Michigan and Chicago, as well as Chesapeake Bay and Baltimore; sampling took place in the cities, along the shorelines, on the waters of the lake or bay and on the opposite shorelines. The study attempted to determine the extent to which pollutant plumes from these cities enhance the deposition and loadings of chemicals to nearby water bodies.

In both the Chicago and Baltimore areas, the concentrations in the urban atmosphere greatly exceed those measured downwind, over water or over land, often by a factor of five and sometimes by factors of 10 or even 100. For Lake Michigan, the high concentrations occurring over the lake were associated with winds from the direction of the shoreline between Evanston, Illinois and Gary, Indiana. A substantial amount of the decrease in concentration between the Chicago area and the eastern lake shoreline in Michigan has been linked to enhanced deposition to Lake Michigan.

It appears that the source of the urban PCB plume exhibited at Chicago and elsewhere is volatilization from open sites that can be affected by variations in ambient temperature, such as landfills, open spill sites and abandoned and unremediated industrial process sites. The extent of the transport of PCBs from a city such as Chicago indicates the presence of some hotspots, such as transformer yards, abandoned industrial sites and land fills, as well as a large general background signal coming from PCBs that have been sorbed onto various surfaces through volatilization and deposition cycles occurring with variations in ambient temperature. Identifying and quantifying these sources would be crucial to any effective deposition reduction strategy.

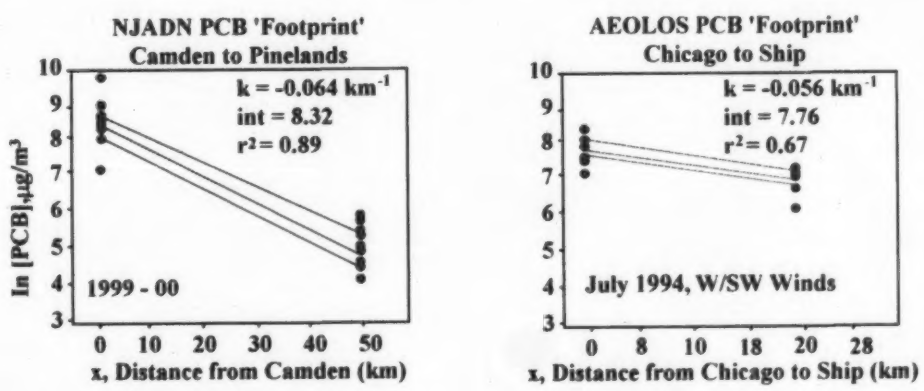
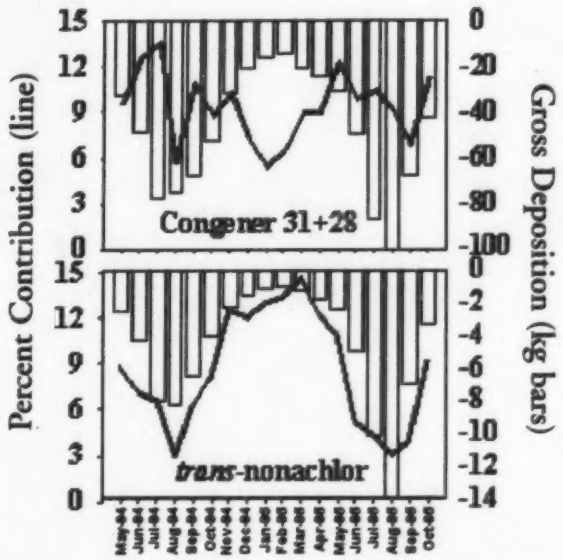


Figure o. PCB 'Footprints'



Monthly whole-lake gross deposition (bars) of PCB 31 + 28 (top plot) and trans-nonachlor (bottom plot). The percentage contribution of the whole lake load from the Chicago site is described by the solid line for each month of the LMMB field season.

Figure p. Monthly whole-lake gross deposition of PCB 31 + 28 and trans-nonacholor

To gain a sense of the possible extent of the 'footprint' of atmospheric emissions from Chicago and other urban areas in the transport and deposition downstream, Steve Eisenreich evaluated AEOLOS and NJADN (New Jersey Atmospheric Deposition Network) data and determined a downwind decay rate of approximately six percent per kilometer, resulting in a reversion to background levels at approximately 50 km downwind.

The Eisenreich scenario assumes that the decrease in atmospheric PCB concentrations away from Chicago and other source areas is due to dispersion and dilution under transport, and removal by deposition and atmospheric loss processes. Figure o. demonstrates this phenomenon for PCB concentrations from Chicago to an over-water sampling site 20 km away, and from Camden - Philadelphia to the Pinelands, New Jersey site 50 km away. The downwind zone of influence is on the order of 50 - 60 km in both cases although the diurnal variation in the magnitude of this zone can be substantial (See Figure l).

Hornbuckle estimated that 2 - 20 percent of the gas-phase PCB atmospheric loading to Lake Michigan originates from Chicago, depending on the congener considered and the time of year. Overall, Chicago accounts for approximately 10 percent (about 300 kg per year) of the total annual PCB input to the lake. Figure p. illustrates the percentage contribution to the whole-lake *gross* deposition from the Chicago site for one PCB congener group (PCB #31+28), showing a highly seasonal variability, with the greatest deposition occurring during the summertime, when air concentrations are high. (Note that gross depositional loads are assigned a negative value, consistent with the equation used to calculate them.)

4.3.6 Actions Supported by the Lake Michigan Models

While the Great Lakes Air Toxics Inventory is one of the more comprehensive regional efforts, there is need for improvement. For example, as noted above, modelling and ambient and deposition measurements for PCBs and dioxin indicate that source data are not adequate to account for the loading to the lakes. The inventory for specific pollutants should be improved, as noted above, by focusing on a specific geographic area, such as a 100 km radius from Lake Michigan for dioxin, and on specific point source sectors and areal emissions, such as burn barrels or landfills. Various workshop presenters noted that, for banned contaminants, the reservoirs in the environment, such as sediment, tillage residue and landfill contents, are of much greater significance than the point sources currently included in the inventories. Emissions associated with such reservoirs must be better defined.

More effort is needed to refine areal emission factors generally in the U.S. and Canadian inventories. Several presentations highlighted the need to include PCB and emissions of other persistent toxic substances from landfills, as estimates of PCB and emissions of other persistent toxic substances from individual landfills in Chicago (Hsu) and New York (Eisenreich) tend to dwarf other sources currently included in emission inventories. In addition, wastewater treatment plants, sludge drying beds and sludge used as landfill cover may all be significant sources of atmospheric PCBs and emissions associated with them should be measured. Other source sectors identified for improvement or establishment of emission estimates include:

- off road and heavy duty vehicles;
- confined disposal facilities for contaminated sediments;
- transformer storage yards; and
- highly contaminated brownfield or former industrial sites.

Given that urban areas are significant sources of PCBs, as well as other persistent toxic substances, to the atmosphere and nearby water bodies, and that each urban area may contain many of the above sources, it is imperative to better quantify emission estimates as a basis for reduction programs.

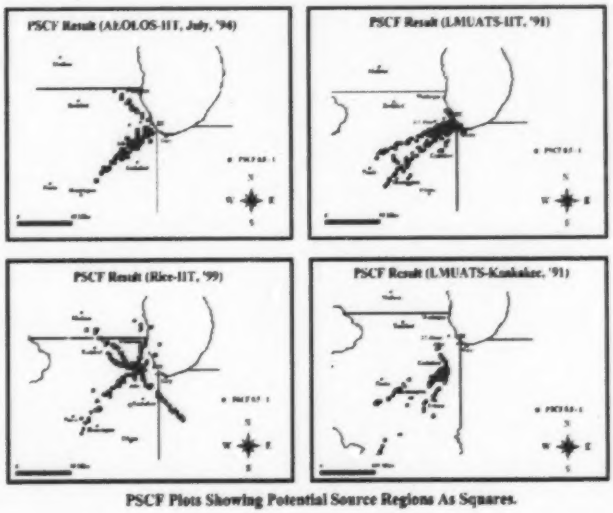
4.3.7 Options for Estimating Emissions

Alternative emission estimation methods are needed, particularly in the urban setting, to assist in the identification of sources and the apportionment of the observed pollutant loadings to those sources. Source apportionment modelling using ambient monitoring data can be used to back-calculate emissions and thus identify or verify sources.

Several promising techniques were presented at the workshop. Dr. Tom Holsen and Ying-Kuang Hsu demonstrated that receptor models and factor analysis can be applied to ambient concentration and related meteorological data to zero in on localized, high emission factor sources of PCBs. Following such identification, sites can be further isolated and downwind measurements taken to confirm the source and estimate the quantity of the PCBs emitted.

In their work, the Potential Source Contribution Function (PSCF) was used to identify PCB sources to southern Lake Michigan. Major differences of this study from prior PSCF applications were the small local area considered and the modelling of semi-volatile organic compounds mostly in the vapor phase. Prior applications of PSCF were regional-scale and sources were resolved to within a hundred miles.

This PSCF modelling in the vicinity of Chicago resolved three PCB source directions: 1. the northwest direction pointing to Madison, Wisconsin; 2. the southwest direction between Joliet and Chicago; and 3. the neighborhood of Lake Calumet. Figure q. illustrates several PSCF model plots in which the alignment of the squares indicates the general directions of potential significant sources of PCB emissions.



PSCF Plots Showing Potential Source Regions As Squares.

To support and build upon the PSCF results, several five-hour, upwind and downwind air samples were taken near potential sources in areas identified as having high PSCF values, as well as other sites that were suspected of being sources of PCBs. Municipal sludge drying beds, a transformer storage yard and a landfill were verified as significant PCB sources based on downwind concentrations 1.5 to 5.3 times the upwind concentrations.

The transformer storage yard exhibited some of the highest downwind PCB concentrations measured during this study, yet it is not currently listed in U.S. EPA's PCB Transformer Registration Database. A closer investigation of the sludge drying operation suggested that its emissions could be three times greater than the 1996 estimated U.S. National Toxics Air Emission Inventory for PCBs in EPA Region 5. Results of upwind and downwind sampling are provided in Table 4.

Given that it would not be practical to use upwind and downwind measurement techniques to identify all the contributions of volatilizing PCBs, Eisenreich and Hornbuckle have proposed a method for predicting emissions from major source regions, such as urban areas, using historical infrastructure and census information, and data on local climate regimes. Using this broadly available information as a screening tool and direct ambient measurement for validation, this method or model could be used to calculate a first estimate of the extent of probable urban volatilization of contaminants such as PCBs, dichlorodiphenyltrichloroethane (DDT) and others.

Results to date indicate that use of the 1970 Cook County (Chicago) census data explained 60 percent of the variability in PCB concentration in the Lake Michigan Mass Balance Study data set and ambient temperature explained about 30 percent. Thus, in the case of PCBs, ambient temperature and population apparently can be used as inputs to a model that could provide a first estimate of the magnitude of the areal environmental reservoir.

Further development of this model requires more rigorous application in other urban and industrial centers for which there are good PCB concentration data and other locales for which there are very few or no measured values, particularly newer urban areas not strongly associated with PCB use. This model may offer a means to develop regional and continental emission inventories for PCBs and other persistent organic pollutants. When coupled with source-receptor models, emission inventories may be developed for compounds for which the usual inventory methodologies are inapplicable.

Figure q. PSCF Plots Showing Potential Source Regions as Squares

Table 4 **Potential Sources: Upwind and Downwind PCB Concentrations**

Date	Site	PCB Concentration ng/m³	
		Upwind	Downwind
07/06/99	Calumet East Drying Beds	2.87	5.47
07/02/99	Stickney Drying Beds	NA	2.17
08/16/98		NA	1.92
08/13/98	CID Landfill	NA	5.13
07/04/99		1.93	3.99
08/16/99		1.23	2.47
08/14/98	ComEd Transformer Storage Yard	NA	11.89
08/15/99, AM		1.41	2.11
08/15/99, PM		1.33	2.73
08/17/99, AM		NA	3.29
07/20/00, AM		1.21	6.49
07/20/00, PM		1.53	8.07

Another approach to supplementing emission inventories, particularly for banned and current use pesticides, is the application of the Scholtz Pesticide Emissions Model (PEM) to determine releases to the atmosphere. This modelling technique, in the absence of other data, can use recommended application rates or can be improved by the establishment of pesticide-use databases. It also can be applied to estimate emissions of residual banned pesticides if historical usage data of reasonable quality are available or can be derived.

4.4 AMBIENT MEASUREMENTS – INTERPRETATION AND USE

The Great Lakes data set is among the best in the world in terms of temporal span and quantity and quality of measurements. The 20 years of PCB data in the Great Lakes are not available for any other ecosystem. In addition, the Lake Michigan Mass Balance Study has a very high quality database. The entire Great Lakes database provides a unique opportunity to further understanding of pollutant cycling and evaluate future pollutant levels. However, as these data are used in various models, and the complexity of the system is unveiled, some enhancements would be necessary to further understand pollutant dynamics. A key question is how to strategically obtain additional, more refined ambient data within existing program limitations.

Cohen indicated that, at the moment, there are only five ambient dioxin measurements from 1996 suitable for use in model calibration, Figure r., and none of these is located in the Great Lakes basin, as dioxin is not included in the Integrated Atmospheric Deposition Network (IADN).

However, a new dioxin monitoring program, the National Dioxin Ambient Monitoring Network, composed of 29 sites nationwide, including some in the Great Lakes region, is under development in the United States. New dioxin monitoring sites should be located in rural areas, as measurements made in urban areas can't clearly determine the origin of the dioxin due to the pronounced complexity of the spatial variability of emissions and meteorological conditions within such areas. Also, much of human dioxin exposure appears to come from the food chain via agricultural products rather than inhalation, suggesting that ambient air concentrations of dioxin in urban areas are not of the same significance from a public health standpoint.

There is very significant variability in space and time in the concentrations of many of the pollutants of concern in Lake Michigan. As a result, at Chicago, a single measurement reflects only that sampling period and cannot be taken as representative of any longer time span. Rather than depending on a limited number of monitoring sites to determine the temporal and spatial variation in these over-lake concentrations – efficient, appropriate ways to monitor, interpolate and interpret pollutant levels are needed in order to estimate concentrations over the entire lake with more accuracy. Long-term averages will not reflect the influence of meteorology or other factors driving changes in concentration. As illustrated by Dr. Hornbuckle's work, while averages may be adequate for some applications, modelling processes and determining the significance of sources requires data that are discrete over the shortest possible time frame.

The Sleeping Bear Dunes IADN site clearly registers lower PCB concentrations than every other site in the Lake Michigan basin, including over-water sampling locations. Hornbuckle suggested that this underestimation indicates that long-term studies using these data do not appropriately describe regional PCB concentrations and associated loadings. Efforts should be made to resolve this issue.

Hsu also indicated a need for ambient concentration data obtained over relatively short sampling periods; otherwise the sample may be influenced by numerous sources and therefore less useful for receptor modelling. In some cases, finer spatial-scale resolution in meteorological databases also is needed, particularly to account for the behavior of urban or agricultural plumes and to allow incorporation of the grasshopper or revolatilization effect into models.

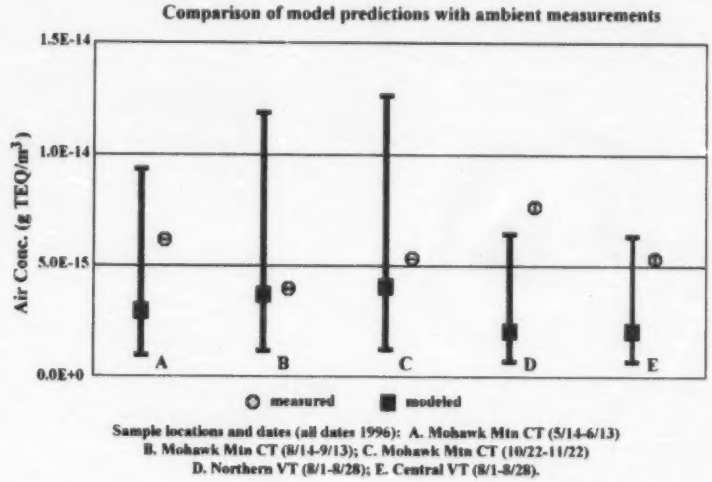


Figure r. Comparison of Model Predictions with Ambient Measurements

4.5 APPLICATION OF MODELS

Several workshop presenters suggested the need for more information on the non-atmospheric pollutant loading pathways to Lake Michigan in order to better know the relative contribution of pollutants of concern from atmospheric deposition. For example, Cohen summarized two crude estimates of the relative contribution of atmospheric deposition to the total loading of dioxin to Lake Michigan — both ranging between 50 and 100 percent (see Table 5). The overall contribution of the atmospheric pathway of PTSs relative to other loading pathways remains uncertain and needs to be better quantified.

The Lake Michigan Mass Balance Study should be completed to provide further information on non-atmospheric pathways. Using the wealth of data generated in 1994-1995 for PCBs, mercury, atrazine and trans-nonachlor, indicative estimates of loadings from tributaries, direct discharges, sediment, groundwater and other sources, should be possible. U.S. EPA is encouraged to make a firm commitment to the completion of the Mass Balance Study.

A Multimedia Fate and Transfer Model (MFTM), as described by Dr. F. Wania, may be used to understand the behavior of semivolatile chemicals that move among more than one environmental compartment (e.g. atmospheric reservoir, soils, vegetation, water, and sediments) over periods of a decade or more. While this type of model has relatively low spatial resolution compared to others, it allows the description of conditions in various compartments of the environment over long time periods, making it useful in working with persistent chemicals.

Table 5 Estimates of the Percent of Lake Michigan Dioxin Loadings Attributable to the Atmospheric Deposition Pathway

Study	Fraction of Current Loadings Contributed Through Atmospheric Pathway
Cohen *et al*[3]	PCDD/TEQ: 50-100 (central estimate: 88)
Pearson *et al*[2]	PCDD: 50-100 PCDF: 5-35

[2]Pearson, R.F., D.L. Swackhamer, S.J. Eisenreich, and D.T. Long (1998).
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[3]Cohen, M., *et al*, 1995. **Quantitative Estimation of the Entry of Dioxins, Furans, and Hexachlorobenzene into the Great Lakes from Airborne and Waterborne Sources.**
Flushing, NY: CBNS. Final Report to the Joyce Foundation.

4.6 CONCLUSIONS AND RECOMMENDATIONS

4.6.1 Core Findings

- Given the availability of appropriate data, the fate of several contaminants prominent in the Great Lakes, including dioxin, PCBs and pesticides, such as lindane, chlordane and others, can be effectively examined through the application of models.
- Similar to their application for the development of management strategies for ozone, models can now be effectively applied as necessary tools for identifying and broadly ranking sources of selected persistent toxic substances entering the Great Lakes by atmospheric transport and deposition.
- Source-receptor models can be used to quantify the contributions of specific point and areal sources of deposition to the Great Lakes within established bounds, given adequate information on 1. the physical and chemical properties of the contaminant; 2. emission inventories; and 3. ambient measurements for verification.
- Of these factors, an examination of several source-receptor models has established that the quality of their predictions is chiefly dependent on the accuracy of associated emission inventories.
- There is significant spatial and temporal variability in the concentrations of several pollutants of concern over Lake Michigan. Specific to the Sleeping Bear Dunes Regional IADN site, measurements taken there appear to underestimate concentrations of air toxics, particularly PCBs, likely due to site characteristics and local meteorology.
- The Lake Michigan Mass Balance (LMMB) and model applications in other urban locales indicate the dominance of PCB volatilization from uncharacterized areal sources rather than permitted point sources or established areal sources. It is likely that such sources also will prove significant for other banned or byproduct persistent toxic substances.
- Further application of source-receptor models to PCB transport and deposition must await the development of more comprehensive inventories, as existing inventories seriously underestimate PCB emissions. However, other modelling to date has identified several likely dominant areal sources.

4.6.2 Recommendations

The IAQAB makes the following recommendations to the IJC.

Sources and Loadings

There is a clear need to place the relative loading of persistent toxic substances from atmospheric deposition in context with the loading of these substances from all pathways to Lake Michigan and the other Great Lakes.

- **Recommend to the Parties that the completion of the Lake Michigan Mass Balance Study for all pathways is crucial to development of an effective control strategy and that U.S. EPA should expedite its prompt conclusion.**

The Lake Michigan Mass Balance Study targets only four pollutants. At the present time, little information is available regarding the relative importance of atmospheric deposition to the loadings of other pollutants to Lake Michigan, or for essentially all pollutants of concern to the other Great Lakes.

- **Recommend to the Parties that basic mass balance information should be developed for other pollutants of concern in Lake Michigan, as well as pollutants of concern in other lakes.**

Current emission inventories must be improved and extended to areal sources if more precise model outputs and an effective control strategy are to be developed.

- **Recommend to the Parties that the following immediate actions be taken.**

a. **For dioxin, review and compare the Great Lakes Air Toxics Emissions Inventory and the inventory developed by Dr. Cohen, with the goal of improving the dioxin inventory for the region, particularly for major point sources. The enhancement of emission factors, other parameters necessary to modelling, and production or process data should be significant elements of this effort. Specific to Lake Michigan, emissions from major sources within 100 km of the basin should be confirmed, preferably by a combination of source testing and data quality review.**

b. **Support further quantification of dioxin emissions associated with backyard residential waste burning, including refinement of areal emission factors and determination of the extent of this practice on a regional basis.**

c. For a number of persistent toxics, including PCBs, chlordane, mercury and critical banned pesticides, perform a review of current and historical land-use records, along with targeted modelling and monitoring at urban centres using one or more of the techniques presented at the November 2000, IAQAB workshop in Milwaukee, Wisconsin to estimate potential areal loadings.

d. Undertake an air toxics monitoring and measurement program designed to identify open sources of PCBs, such as contaminated brownfield and storage and waste management sites. This monitoring program should have a mobile capability with simplified procedures for deployment and relocation, as well as for upwind and downwind studies or measurements. All measurements should be coordinated with modelling predictions. Immediate priority should be given to estimating emissions from individual landfills, wastewater sludge drying operations and open transformer storage facilities for inclusion in the inventory. Measurement of other banned contaminants should also accompany such programs, as feasible.

Modelling

- Recommend to the Parties that the models and strategies for Lake Michigan and its related urban area of Chicago, reviewed at the workshops, should be developed further and their application extended to other urban areas and other lakes within and outside the Great Lakes basin.

- Recommend to the Parties, that as a first step, the adequacy of information on contaminant physical and chemical properties, as well as available emissions and ambient concentration data, should be determined prior to any modelling application.

- Recommend to the Parties that the Lake Michigan Mass Balance dataset, including available sample extracts and related measurements, and appropriate model(s), be used for the prediction of the sources and transport of other air toxics, such as polycyclic aromatic hydrocarbons (PAHs), beyond the original LMMB target compounds of mercury, PCBs, trans-nonachlor and atrazine.

- Recommend that the Parties explore the application of other multimedia non-steady state models as an effective method of determining the longer term trends in the deposition of persistent toxic substances to the Great Lakes.

- Recommend that the Parties apply models for pesticide volatilization from soils to fields within and outside the Great Lakes basin where significant concentrations of banned pesticide residuals are detected, both to estimate the possible contribution of continued cultivation and to develop a code of best practice for such areas.

- Recommend that the parties begin a predictive modelling effort to identify regions around the Great Lakes for which there is a high probability of substantial emissions of persistent toxics. Derivation and verification of any such modelling technique should be focussed initially in major urban areas.

Ambient Sampling

- Recommend that the Parties continue ambient air sampling over the surface of the lake to provide better estimates of representative regional concentrations of these pollutants and improve the characterization of their air/water exchange.

- Given the regional designation of the Sleeping Bear Dunes IADN ambient monitoring site, recommend that the Parties interpret data collected at this site with assistance from atmospheric models that address air/surface dynamics and include meteorological models.

- Ensure that any modelling effort be supported by adequate ambient measurements to provide verification for any model output.

Source Control Initiatives

- The recently completed Delta Institute Lake Michigan Regional Air Toxics Strategy identifies linkages and opportunities for further air toxics reductions via various, ongoing, specific programs and initiatives under state and U.S. federal legislation. The IJC, through their relevant advisory boards, should review this proposed strategy and comment on its applicability to deposition reductions in the Lake Michigan and other Great Lakes basins from a binational perspective.

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Appendix I Significant Activities Under Annex 15 of the Great Lakes Water Quality Agreement

Background

In the early 1980s, Dr. Steve Eisenreich and Dr. William Strachan, in one of the first estimates of the contribution of atmospheric deposition to the contamination of the Great Lakes, determined that approximately 90 percent of polychlorinatd biphenyls (PCBs) loading to Lake Superior could be attributed to deposition from the atmosphere.

In its 1985 report to the IJC, the Great Lakes Water Quality Board (WQB) presented a list of 11 (12) Critical Pollutants (Table 6) . For every listed pollutant, there was reason to believe or evidence to support the supposition of the atmosphere as a significant pathway. In response, the IJC's WQB, Science Advisory Board (SAB) and International Air Quality Advisory Board (IAQAB) began assembling an international emission inventory of persistent toxic substances. These and other developments contributed to the inclusion of Annex 15, Airborne Toxic Substances, in the 1987 Protocol to the Great Lakes Water Quality Agreement.

Table 6 Critical Pollutants

Total polychlorinated biphenyl (PCB) Mirex
Hexachlorobenzene Dieldrin DDT and metabolites
2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)
2,3,7,8-tetrachlorodibenzofuran Benzo-a-pyrene
Alkylated lead Toxaphene Mercury

Activities Since 1987

Annex 15 committed the governments of the United States and Canada, the parties to the Agreement, to the reduction of atmospheric deposition of toxic substances, particularly persistent toxic substances, to the Great Lakes basin ecosystem through research, surveillance and monitoring, and ultimately, the implementation of additional pollution control measures. Models to determine the significance of atmospheric loadings to the Great Lakes system, relative to other pathways and the sources of such substances from outside the Great Lakes system, also were to be developed.

The Integrated Atmospheric Deposition Network (IADN) was established in the Great Lakes basin as a direct response to Annex 15 and built upon the expertise available under the IJC for its design. The network was to: 1. determine atmospheric loadings of toxic substances by quantifying their total and net atmospheric input to the Great Lakes system; 2. define the temporal and spatial trends in the atmospheric deposition in the basin; and 3. support development of Remedial Action Plans and Lakewide Management Plans pursuant to Annex 2 of the Agreement.

Additionally, the Parties, in cooperation with state and provincial governments, committed to develop and implement measures to control emission sources of toxic substances and eliminate the emission sources persistent toxic substances in cases where the atmosphere is a significant contributor to the Great Lakes system. The governments were to review their progress in implementing this annex and report to the IJC biennially, commencing with a report no later than December 31, 1988.

Addressing the monitoring element of the annex, a 1989 report from the IJC's Integrated Atmospheric Monitoring Task Force established the basis for the international Integrated Atmospheric Deposition Network (IADN). The network continues to supply valuable data on concentrations of many, but not all, targeted persistent toxic substances.

Also in 1989, in response to the research element of the annex, the IAQAB compiled a first inventory of atmospheric sources of the Critical Pollutants (Voldner and Smith, 1991). The report concluded that "a larger undertaking ... on toxic chemical emissions will be required to provide the necessary information on atmospheric emissions and their subsequent deposition in the Great Lakes region." The Parties did not carry on this specific task, choosing rather to integrate some of the critical pollutants into their national and regional emission inventory efforts. Notwithstanding some observed progress in emission inventory activities, an identical statement could be made today with regard to the Level I and Level II contaminants from the 1997 Binational Toxics Strategy (BNS) list.

Heavy metals, organochlorines and pesticides currently used in North America were the focus of subsequent modelling efforts. Annual estimates of deposition to individual lakes and basins have been computed for sulphur and nitrogen during the period from 1980 to 1988; for toxaphene during approximately 1980; and for mercury during a thirty-day period in late 1980.

The IAQAB noted that the quality of these model-estimated depositions would be very dependent upon the quality of emission inventories, knowledge of the chemical and physical processes affecting their lifetimes in the atmosphere, and support for further model development. This statement was explicitly reinforced in the IJC's *Seventh Biennial Report on Great Lakes Water Quality* (December 1993).

This same report also noted the comments of the IAQAB on the inadequacy of emission inventories with regard to development of a Lake Superior Zero Discharge Demonstration Program and recommended that "federal governments provide coordinated national inventories of toxic air emissions ... " The Commission also noted, "a focus on research to improve understanding of the pathways, fate and effects of airborne toxic substances, required by Annex 15, has not occurred. Specifically a research program emphasizing atmospheric processes, transfer coefficients, and gas exchange processes is needed."

HYSPLIT Modelling by Dr. Mark Cohen, National Oceanic and Atmospheric Agency (NOAA)

In March of 1995, the Work Group on Parties Implementation of the SAB was among the first to preview a report by Dr. Barry Commoner and Dr. Mark Cohen from the Center for the Biology of Natural Systems, SUNY Queens College, titled *Quantitative Estimation of the Entry of Dioxins, Furans and Hexachlorobenzene into the Great Lakes from Airborne and Waterborne Sources.* Responding directly to one element of Annex 15, the report describes a first attempt to link, through modelling, the atmospheric deposition to the Great Lakes of dioxin and related compounds from major source sectors throughout the U.S. and Canada. Its outputs include a first analysis of the relative importance of distinct sources and source regions to overall deposition.

In subsequent months, the IAQAB contracted with Dr. Cohen to report on preconditions necessary to allow modelling of the atmospheric transport of the 1985 Critical Pollutants and other BNS contaminants. Specifically, a review of the adequacy of available information and programs in four areas was requested. The four areas are: 1. the capability or potential of the BNS pollutants to be transported for long distances in the atmosphere; 2. the availability and accuracy of emission inventories for these contaminants in the United States and Canada; 3. application of models to describe the atmospheric fate and transport of these compounds, with particular attention to studies involving deposition to the Great Lakes; and 4. the adequacy of existing ambient monitoring information to estimate the overall loadings of BNS contaminants to the Great Lakes and to serve as benchmarks against which to evaluate atmospheric models.

Dr. Cohen's work identified significant concerns over the incomplete data associated with physical and chemical properties of the contaminants, leading to uncertainties regarding their atmospheric fate and transport; the quality and comprehensiveness of emission inventories in the U.S. and Canada; the paucity of efforts to model transport and deposition, especially with respect to source-receptor relationships; and the absence of some critical pollutants from ambient monitoring programs.

Since 1997, the IAQAB and Dr. Cohen have continued to model atmospheric transport and deposition of a limited number of BNS contaminants. Due to the limitations outlined above, modelling could only be attempted for dioxin, cadmium and mercury. The dioxin project is largely finished and a mercury model should be available in late 2002. Completion of the cadmium modelling remains uncertain due to data and resource constraints. Modelling for atrazine, a non-BNS pesticide, also has been developed, but production of a final and more current version requires further support.

The IAQAB and WQB Workshop Romulus, Michigan (1997)

In May 1997, the IAQAB and WQB hosted a workshop in Romulus, Michigan to consider loadings, sources and pathways of persistent toxic substances. The focus was on the quantification of sources and pathways, particularly through the atmosphere, and further control of such substances, especially through 'beyond compliance' initiatives. The boards, echoing the Cohen report to the IAQAB, noted that determining the significance of atmospheric deposition to the total burden of PTSs in the basin requires improved source and process inventories, a further determination of physical and chemical properties of the contaminants, further monitoring of their presence in the environment, and additional modelling to link sources and receptors.

The Delta Institute Workshops on Atmospheric Deposition (1999)

The first Delta Institute workshop, held in May 1999, focussed on the findings and implications arising from recent atmospheric research. The second workshop, held in October 1999, focussed on issues prompted by the research

results of: setting priorities for research that address policy needs, integrating and making research results more readily available; coordinating a national strategy for estimating and controlling atmospheric deposition; and increasing international focus and coordination for this issue.

General conclusions reached at these workshops suggest that current research, data and models could identify source areas and source sectors, and, if they are substantial enough, certain large point sources of persistent toxic substances. To date, research continues to affirm that atmospheric deposition must be addressed if Great Lakes water quality goals for persistent toxic contaminants are to be met. It was acknowledged that modelers must present their work more effectively if it is to be used as an appropriate tool for policy formulation.

These workshops also reinforced the notion that the long-range transport phenomenon presents significant policy challenges. The Great Lakes region cannot address its contamination burden alone. National and international programs controlling or eliminating the use and release of persistent toxic contaminants would have a direct bearing on reducing loadings to the lakes. Further control of both domestic and international sources of atmospheric deposition depends on a strong, innovative strategy integrating regional, national, binational and international initiatives.

A key recommendation from the latter workshop advocated the development of an atmospheric deposition strategy using Lake Michigan as a case study. A strategy developed for a specific region using real data was seen as a useful step toward establishing policies for all the Great Lakes and in forming national and international policy-making on atmospheric deposition.